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"CONCERNING $\frac{T_1 - T_0}{T_1}$; OR, THE LIMIT OF EFFICIENCY IN HEAT ENGINES."

By PROF. R. H. THURSTON.

Fully appreciating the mathematical skill, the familiarity with heat-dynamics, and all the courtesy illustrated in the paper published recently in the JOURNAL under the above title, in which the "thermo-dynamic heresy" detected by its author is so ably attacked, and admitting the conclusions therein reached, the writer would suggest that the truth may be best exhibited by quite a different method.* In fact, the main question calls for but very brief consideration and may be solved by very simple logical methods, based on well-proven and generally known facts which have been determined by scientific investigation and upon principles equally well-settled and generally understood.

*In justice to its author, it should be stated that the paper containing this "heresy" was prepared while he was suffering from nervous exhaustion and prostration due to various physical causes and mental anxieties, the extent and the effects of which were not at the time either realized or suspected. A long period of depression terminating in serious illness extending over many months, from which illness recovery has only recently been apparently assured, will account both for the original error and for its tardy recognition.

The question primarily at issue in the case considered was whether the thermal changes of energy occurring in a fluid doing work and having work done upon it when its constitution is that of a perfect gas, were essentially different so far as they affect adjacent bodies, from those occurring when the working substance condenses during expansion against resistance, as does steam in the steam engine. This point settled, no further discussion is needed.

The question being, whether all working substances are, as transferrers of heat, equally efficient in heat engines, the case is covered by a well-known principle of mechanics:—In any mass or system of bodies, no interchanges of energy and no interaction of forces among those bodies can produce any change in the action of the mass upon bodies external to itself.

Now, as the characteristics which distinguish perfect gases from those which, like steam, condense while doing work upon external bodies, are due entirely to differences in interactions occurring among their molecules due to their own internal and inherent attractive (and possibly inherent repellant) molecular forces, it at once follows that, as receivers and transmitters of heat energy to external bodies, they will be alike and subject to the same laws. No interchange of energy externally, such as results in the closer approximation of the particles of one portion of a vapor, in consequence of its surrender of energy to other molecules, can affect the action of the mass, as a whole, upon bodies external to itself.

Another statement, equally simple, may serve:—A given quantity of heat entering an engine and doing work therein—whatever the amount and whatever the conditions—that quantity of heat energy has, initially, a measure Mh, in which M measures the quantity of matter, *i. e.*, the mass of the working substance, and h is the virtual head which, multiplied into M, gives a product equal to the total initial energy. All subsequent changes which attend the operation of the engine are due to variations in the value of h; since they are all due either to changes of molecular velocities with changing temperature or to changes of molecular distances due to modification of repellant forces and changes in the total quantity of heat present in the expanding or contracting mass.

Throughout every operation, the value of M remains constant and must so remain as long as the law of the persistence of matter continues. If then, the mass remains constant, it is a matter of indiffer-

ence, so far as any thermodynamic action is concerned, what kind of matter has given the value M. This being the case, it is a matter of indifference, in any thermodynamic problem, what working substance is used or assumed; every principle applies equally well whether the heat engine be a perfect gas engine, or a steam, or other vapor engine.

Proposition A—"It is impossible for any heat engine to perform work by the expansion and contraction of the volume of its working substance without rejecting heat"—is correct under all attainable conditions, so far as is yet known, and every such engine must reject heat.

The proposition, although correct, when rendered properly specific as intended, is if unqualified, not only not proven by the reasoning adopted, but may be disproved by the same general method and using the same quantities.

Thus: let the engine R be driven backward by S, as suggested in the JOURNAL, p. 154, the latter, however, acting under those conditions which admittedly imply rejection of heat, we then have:

$$W_1 = J\,(Q_1 - Q_0) \text{ and } W^1{}_1 = J\,(Q^1{}_1 - Q^1{}_0);$$

then,
$$Q_1 - Q_0 = Q^1{}_1 - Q^1{}_0,$$

and if the two engines take in heat at the same temperature, it follows that the engine S, by exerting a certain quantity of energy between the initial temperature t and a lower temperature t_0, may convey an equivalent amount of heat from the grade t_1 to a higher temperature t_2. The point here overlooked is the fact that $Q_0 > Q^1{}_0$.

Now suppose that S works down to absolute zero, and thus avoid the rejection of heat, we have, as in the original:

$$J\,(Q_1 - Q_0) = J\,(Q_1{}^1 - Q_0{}^1) = J\,Q^1{}_1, \text{ and}$$
$$Q_1{}^1 = Q_1 - Q_0$$

and it follows—since S certainly does not now reject heat, for none is left to reject—that the second principle assumed is false, as well as that it is possible for a heat engine to perform work without rejecting heat. The true conclusion is obviously that *only under certain conditions, which we cannot now see any way of securing, can a heat engine do work without rejection of heat.*

Proposition A, to be correct, requires this limitation, and the second assumed principle is as evidently defective in not being sufficiently specific. This latter fact has been fully recognized by Maxwell, Tait and other writers. As put by Clausius, "heat cannot, of itself, pass from a

colder to a warmer body," it is sufficiently and obviously right and is analagous to the statement, "Water cannot, unaided, flow upward."

Thompson's statement, "It is impossible, by means of inanimate material agency, to derive mechanical effect from any portion of matter by cooling it below the temperature of the coldest of the surrounding objects" is analagous logically, not physically, to the statement that "no machine can, of itself, cause water to flow upward." In either case, the desired effect can be actually produced only, so far as we now know, by the sacrifice of some part of an original stock of energy. Clerk–Maxwell, it is true, has suggested in his so-called "demon hypothesis," how it is at least conceivable that work might be done by cooling any mass of elastic gas or vapor below the temperature of surrounding bodies, and the writer has suggested a singular and equally conceivable "physical possibility" by which the same result is reached; but both are equally impracticable.

It is readily seen why it has been difficult to frame a correct enunciation of the principle. It is one of those facts which come of natural conditions which can be learned, and limitations detected, only by experiment, or by mathematical deduction from experimentally proven laws, based in turn on facts shown by experiment or by observation; it is not a general law in the same sense with the "first law" of thermodynamics. We can only assert that it is correct under all conditions which seem to us attainable, and that the results are then practically the same as if it were an absolute and mathematically accurate general principle.

It may be seen that the efficiency of an actual engine is dependent, not only upon the range of temperature adopted, but also upon the method of disposing of heat rejected. Our theory assumes the absolute impossibility of avoiding rejection of heat or of exchanging that of low for that of high grade, or for available natural energy of any other kind.

The whole matter is briefly and well summed up by Tait, who says:* "therefore, *so far as experiment goes, and practical application goes*" (the italics are introduced by the writer), "we may take this improved form of Carnot's demonstration as being absolutely decisive of the important result that no heat engine can be more perfect than a reversible one." We cannot say what experiment may reveal in the future,

* "Recent Advances in Physical Science," by P. G. Tait, M. A., London, 1876.

or what practical applications may follow. We can only assert that it, to-day, seems impossible to do work by the expenditure of heat energy without waste by rejection of energy from the system as a whole, and that it is not known to this day whether or not we must go on throughout the life of the race, or until all mankind is driven into the tropics by the exhaustion of our fuel supplies, wasting a large percentage of all the heat energy now treasured up in our coal fields.

The facts and premises and the logical argument which would best suit the majority of readers perhaps, reads thus:—

1. We know, at present, no other way of making heat energy available in engines than through changes in volume and density of masses pervaded by it.

2. We know, at present, no practicable way of discharging heat from the working substance of a heat engine except by presenting to it a mass at lower temperature.

3. We know, at present, no way of compressing a mass of matter containing heat—that heat not being removed from the mass—without the production of an additional amount of heat precisely equal to that which disappears in the opposite equal change of expansion.*

4. "Heat will not, of itself, pass from a colder to a warmer body."

5. No way is known, at present, of working an expanding body in any heat engine down to the absolute zero of temperature—and thus of depriving it of all heat energy—or of approximating to that state.

6. All heat engines are worked in the presence of and surrounded by matter having a temperature several hundred degrees above absolute zero, which thus presents to the working fluids of such engines a kind of "sea-level" of heat energy.

Now, in every such engine, the working substance having driven the piston to the end of its stroke and thus having attained to a maximum as to volume, and to a minimum as to contained heat energy, it must either be rejected from the cylinder or must be restored to its initial and minimum volume.

But, as just shown, the one operation compels its expulsion with all its heat contents, against the extraneous pressure due to the presence in the resisting fluid of heat energy at or above the "sea-level" of tem-

* It is, however possible, as shown by Joule, for change of volume to occur without transfer of heat. Work must be done to cause change in total amount of heat energy.

perature, while the other action can only occur by compression, with abstraction by surrounding bodies of all heat due to such reduction of volume.

Hence, in all heat engines, so far as we now know, there must be a rejection of unutilized energy from the working cylinder, the proportion of initial heat to that thus lost being determined by the working temperatures adopted, and the absolute amount of waste per pound of working substance being determined by its physical properties and the distance of the absolute zero below minimum working level of temperature.

TESTS OF A BALDWIN LOCOMOTIVE.

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(Continued from vol. lvii, page 272.)

In the following table the diagrams have been worked in pairs for each engine (right and left), and are given with the boiler pressure, revolutions, and the track, for each series of cards. The series are numbered from 1 to 40, Cincinnati to Hamilton; from 1 to 20, Hamilton to Twin Creek, and from 1 to 21, Twin Creek to Dayton.

In column 1 is given the order in which the diagrams were taken; column 2 gives the pressure in the boiler taken simultaneously with the diagrams; column 3 contains the revolutions corresponding with each series of diagrams. As already explained, the engine counter failed after running a short distance, and the revolutions are deduced from the observed time in running between fixed stations. This method, although not as desirable as an actual record of the revolutions by speed counter, was the only means by which the speed could be noted after the counter broke and cannot be in error sufficiently to affect the final results. The distances between stations (of which there were ninety-six in a run of fifty-nine miles) were carefully measured, after the tests, and the time in running from one station to the next was noted to seconds, and by the observer entered in his note book.

Columns 4 and 12 contain the initial pressures averaged for each pair of cards. This is the pressure at commencement of stroke and, as will be observed, is approximately the same for both engines during each of the three runs. Columns 5 and 13 contain the cut-offs in fractions of

stroke measured on the cards. The entire valve motion is earliest for the right engine, although by the marks on the the guide bars, the valve motions were alike for both engines. Columns 6 and 14 contain the fractions of stroke to release. Columns 7 and 15 contain the terminal pressures, or pressures at time exhaust opens. (All pressures are measured from the atmosphere.) Columns 8 and 16 contain the counter pressures at mid-stroke. The effect of speed and terminal pressure on the back pressure will be apparent upon comparison of the values in these columns with the corresponding values in columns 3–7 and 15. Columns 9 and 17 contain the fractions of stroke, estimated from zero to exhaust closure. Columns 10 and 18 contain the mean effective pressure per square inch of piston during stroke (forward and back). Columns 11 and 29 contain the indicated horse-power for each pair of diagrams. The extreme variableness of the resistance under different conditions of speed and track are apparent from these values and the values in column 20 (where the aggregate indicated power is given). For diagrams 39, run from Cincinnati to Hamilton, the aggregate indicated resistance, including friction of the engine in all parts and extra friction due to load, was 30·641. At this time the engines were running "throttled" and "cut back" at less than seventy-nine revolutions per minute, whilst in diagrams 32, with an average cut-off ·58 of stroke and open throttle at 208·33 revolutions per minute, the engines were developing, in the aggregate, 726 horse-power, a mean of 363 horse-power per engine. In column 21 is given the conditions of the track, curve or tangent, grade up or down, deflection of curve, angle at centre and ratio of grade.

As suggested early in the review of the test, the engines were precisely alike, except the piston-rod of left engine was ·0625 in. in excess of standard diameter, otherwise the engines did not differ in measured dimensions; and without data to the contrary it would be reasonable to expect the engines to do equal amounts of work. A careful examination of the table of diagrams will show that, with a few exceptions, probably due to delay in taking the diagrams from opposite sides of the locomotive, the left engine was constantly carrying the heaviest load. In this engine the valve functions are all tardy as compared with the opposite side; but this alone is not sufficient to account for the discrepancy in the loads. According to the De Pambour law "the mean pressure on the piston is equivalent to the resistance" and any attempt to estimate the resistance from an indicator diagram assumes

the correctness of this law. If the steam pipes branching to the cylinders were of unequal area in cross section, then the effect would be appreciated by a reduced initial pressure in the cylinder supplied by the least pipe, and this would appear to be the case in the run from Cincinnati to Hamilton, but in the runs from Hamilton to Twin Creek and from Twin Creek to Dayton the initial pressures differ very slightly.

With equal initial pressures and equal functions of valves, the mean diagrams should estimate alike, and in a coupled engine, when the load for a given interval of time is represented by a constant statical moment, each engine at two points in every revolution of the cranks must be capable of moving the load unaided by the opposite engine. Then by applying the De Pambour law to the problem, the mean pressure at the two points of crank should be equal for equal radii of cranks and opposite engines. If the pistons work on cranks at quarters, then the points at which one engine must be capable of moving the load at mean speed are 90° and 270° in the revolution of the respective cranks.

In a locomotive, when the axes of cylinders are in the same plane as the axis of drivers, then these points would represent a position of piston in excess of half stroke for the back motion, and less than half stroke for the forward motion, and the pressures at these two points referred to effective areas of piston should be alike.

Again, if the resistance to the motion of the engine be a constant quantity, then the mean effective pressure for total stroke into the mean crank arm (both cranks considered) should equal the pressure on the crank pin at 90° and 270° into the minimum crank arm.

The maximum crank for a pair of engines coupled at quarters would be 1·414, the actual radius of crank, and would exist when the cranks were respectively at angles of 45° and 235° from the centre line, and the minimum crank arm would exist when one pin was at 0° or 180° and the other at 90° or 270°, and the mean crank arm would be

$$\frac{1 \times 1{\cdot}414}{2} = 1{\cdot}207 \text{ times the actual radius of crank.}$$

In brief, the maximum crank arm for an engine working singly is the minimum crank arm for a pair of engines coupled at quarters, and as the force applied to the minimum crank arm must be capable of moving the load at mean speed, it follows that this force into the minimum crank arm should equal the mean pressure into the mean crank arm (for both engines).

It has been suggested that the force on the minimum crank arm into

the length of the arm, may be more or less than the mean force for whole stroke into the mean crank arm, and that the momentum of the engine will be increased or diminished accordingly as the moment of the force into the minimum crank arm is greater or less than the moment of resistance.

An engine operating under the conditions first named, would move forward without acceleration or retardation of speed so long as the cut-off, boiler pressure, and resistance was uniform. Whilst under the second conditions, the engine would move forward by successive impulses, and the motion would be accelerated or retarded as the pressure into minimum crank arm was greater or less than the mean pressure into mean crank arm.

In the condensed tables of engine performance, the averages of the table of diagrams are given, together with the duration of run, miles run, miles per hour and distribution of the load.

The friction of engine in all its parts was determined upon the return from Dayton to Cincinnati; the car, containing the observers and invited guests, being detached and the engine running at average speed, while friction cards were taken, as rapidly as the indicators could be worked, from both ends of each cylinder.

The power absorbed by the engine in overcoming frictional resistance is based upon the average of mean effective pressures from the friction diagrams and the speed for each run.

The extra friction due to load has been estimated at *five* per cent. of gross load; the power expended in moving the train is the difference between the indicated horse-power and power absorbed by friction.

In determining the cost of the power, the engines were charged with the total water pumped into the boiler. Some exception may be taken to this method of estimating the economy of performance, but while, for purposes of investigation, it is proper to separate the performance of the boiler from that of the engine, in actual use the economy of the one is largely dependent upon the other. The economy of the boiler might be excellent, whilst the design of the engines was such as to obliterate the efficiency of boiler and render the efficiency of the whole mediocre or poor, and conversely, a good design of engine may be prejudiced by the inferior duty of the boiler. Of the total quantity of feed pumped into the boiler a portion went into the dry pipe as water entrained, a portion was lost by frequent blowing of the safety-valve, and still another portion was lost by the

whistle. In addition to these losses, the drain-cocks of the cylinders were occasionally opened, and a small quantity of steam was wasted in the attempt to make calorimeter observations. Taking the difference between the water pumped into boiler and steam delivered to the engines at *seven* per cent. of the total quantity, then of this quantity but *ninety-three* per cent. was properly chargeable to the engine.

The per centage of steam accounted for by the indicator becomes

$$\frac{85{\cdot}068}{{\cdot}93} = 91{\cdot}47$$

for the run from Cincinnati to Hamilton;

$$\frac{80{\cdot}271}{{\cdot}93} = 86{\cdot}31$$

for the run from Hamilton to Twin Creek; and

$$\frac{83{\cdot}191}{{\cdot}93} = 89{\cdot}45$$

for the run from Twin Creek to Dayton; and the actual steam per indicated horse-power per hour, became for the three independent runs 30·02 pounds, 31·05 pounds and 29.72 pounds, respectively.

A 16 in. non-condensing Harris-Corliss engine, working at 500′ piston speed, initial pressure of 100 pounds above atmosphere and cutting off at $\frac{2}{10}$ of stroke, would require about 21·5 pounds of water per indicated horse-power per hour.

It has been suggested by an eminent English engineer, that of the total power developed by a locomotive, 25 per cent. was absorbed by the engine itself in overcoming friction and working the pumps. The pumps were on during the run for friction diagrams, and the power expended in this direction is embraced in the second quantity under the distribution ot the load.

During the run from Cincinnati to Hamilton the mean indicated load on the locomotive was 291·958 horse-power, and the mean total friction load 33·384 + 12·929 = 46·313 horse-power, and the percentage of total power absorbed by the engine itself in overcoming all resistances becomes

$$\frac{46{\cdot}313 \times 100}{291{\cdot}958} = 15{\cdot}86.$$

During the run from Hamilton to Twin Creek, the mean indicated load was 368·658 horse-power, and the total friction load was 57·632 horse-power, and percentage of total power absorbed by the engine in overcoming all resistances becomes

$$\frac{57{\cdot}632 \times 100}{368{\cdot}658} = 15{\cdot}63$$

During the run from Twin Creek to Dayton, the mean indicated load was 388·502 horse-power, and the total friction load was 61·487 horse-power, and the percentage of total power absorbed by frictional and pump resistances becomes

$$\frac{61{\cdot}487 \times 100}{388{\cdot}502} = 15{\cdot}82$$

or an average of 15·77 per cent. of the total indicated power was expended in overcoming the friction of the engine in all its parts, extra friction due to load and in working the pumps.

In presenting the cost of the power in coal, it is proper to remark that the coal burned during this trial was Pittsburgh No. 2, screened and picked, and is supposed to represent the best bituminous coal available in this part of the country (Cincinnati). Estimating the cost upon the basis of the actual coal burned, is prejudicial to the engines to the extent of unconsumed coal blown out of the stack, and of failure in the boiler to furnish a standard evaporation.

Taking the economy of engines as represented by 30·02, 31·05 and 29·72 pounds of steam per indicated horse-power per hour, or an average of 30·26 pounds for whole trial, and the evaporation per pound of coal (Pittsburgh) as 9 pounds, then the cost of the power becomes

$$\frac{30{\cdot}26}{7} = 3{\cdot}36 \text{ pounds.}$$

It will be remarked, upon examination of the condensed tables of performance of the engines, that whilst the cost of the power upon an evaporation of nine pounds of water per pound of coal is approximately the same for all the runs, the actual cost of the power is respectively 4·238, 7·033 and 5·359 pounds of coal per indicated horse-power per hour. The manifest unfairness of estimating the economy of the engines upon the coal actually burned, could not be better shown, for whilst the expense of steam per hour per horse-power is nearly the same for all runs, the actual coal burned varies from 27 per cent. excess during the third run to nearly 66 per cent. excess during second run, as compared with the coal burned per horse-power per hour during first run.

Assuming the Baldwin Locomotive as representing the best American practice, then two serious defects are apparent from these trials:

First. The economy of boiler should be improved until an average evaporation is had, of nine pounds of steam from temperature of feed

per pound of coal. This evaporation is attainable without impairing the steaming qualities of the boiler.

Second. The valve gear should be so devised as to produce full port-opening for all cut-offs, and the area of port-opening should be calculated for maximum piston speed. It is just as desirable that the initial pressure in the cylinders of a locomotive shall approximate boiler pressure as in the automatic cut-off engine, and this result also is attainable without complicating the valve gear or diminishing the pronounced efficiency of the engine.

Summary of Engine Performance.

Cincinnati to Hamilton.

July 28th, 1878.

Duration of run,	1 hour 26 minutes.	
Miles run,	24·6950	
" run per hour,	17·2290	
Mean revolutions per minute,	100·4730	
" piston speed each engine,	401·8920	
" boiler pressure,	pds. 122·0000	
	Right Engine.	Left Engine.
" initial pressure,	pds. 97·272	99·812
" cut-off in parts of stroke,	·5066	·5486
" terminal pressure,	" 42·547	44·610
" release in parts of stroke,	·8695	·8879
" counter pressure at mid stroke,	" 2·106	2·653
" exhaust closure in parts of stroke	·2736	·2160
" effective pressure,	" 63·447	66·484
Grade of expansion including clearance,	2·124	1·961

Distribution of the Load.

Indicated horse-power,	141·782	150·175
	291·958	
Power absorbed by engine above all resistances,	33·384	
Gross load,	258·574	
Extra friction due to load (·05 of gross load),	12·929	
Power expended in moving the train,	245·645	

Cost of the Power.

Steam per hour to the engines,	9424·60	
Piston displacement per hour to release	28842·31	29425·92

Piston displacement per hour to exhaust closure,	9075·49	7158·46
Volume of clearance per hour,	2520·98	2518·72
Weight of steam accounted for to release per hour,	4353·214	4588·809
" " " retained by cushion per hour	497·909	426·874
" " " by diagrams (total),	3855·305	4161·935
	8017·24	
Percentage of steam accounted for,	85·068	
Steam per indicated horse-power per hour by boiler,	32·28	
Steam per indicated horse-power per hour by diagrams,	27·46	
Coal per indicated horse-power per hour actual evaporation,	4·238	
Coal per indicated horse-power per hour 9 to 1,	3·586	
Relative capacity of engines,	·9441	1·0000
" economy of engines,	1·0000	·9812

Summary of Engine Performance.

Hamilton to Twin Creek.

July 28th, 1878.

Duration of run,	42 minutes.	
Miles run,	15·869	
Miles per hour,	22·670	
Mean revolutions per minute,	124·1790	
" piston speed each engine,	496·7160	
" boiler pressure,	124·0000	
	Right Engine.	Left Engine.
" initial "	106·654	107·538
" cut-off in parts of stroke,	·4928	·5370
" terminal pressure,	43·204	46·773
" release in parts of stroke,,	·8669	·8853
" counter pressure at mid stroke,	5·495	6·353
" exhaust closure in parts of stroke,	·2863	·2229
" effective pressure,	62·545	65·812
Grade of expansion, including clearance,	2·183	2·004

Distribution of the Load.

Indicated horse-power,	179·603	189·055
	368·658	
Power absorbed by engine above all resistances,	41·262	

Gross load,	327·396
Extra friction due to load (·05 of gross load),	16·370
Power expended in moving the train,	311·026

COST OF THE POWER.

Steam per hour to the engines,	12311·94		
Piston displacement per hour to release,	35541·03	36261·85	
" " " exhaust closure,	11737·62	9129·98	
Volume of clearance per hour,	3115·80	3113·00	
Weight of steam accounted for to release per hour,	5427·37	5849·11	
" " retained by cushion " "	758·99	634·33	
" " by diagrams,	4668·38	5214·78	
	9883·16		
Percentage of steam accounted for	80·271		
Steam per indicated horse-power per hour by boiler,	33·396		
	26·172	27·582	
Steam per indicated horse-power per hour by diagrams,	26·877		
Coal per indicated horse-power per hour by actual evaporation,	7·033		
Coal per indicated horse-power per hour 9 to 1,	3·711		
Relative capacity of engines,	·9434	1·0000	
" economy " "	1·0000	·9489	

SUMMARY OF ENGINE PERFORMANCE.

Twin Creek to Dayton.

July 28th, 1878.

Duration of run,	42·5 minutes.	
Miles run,	16·267	
Miles per hour,	22.965	
Mean revolutions per minute,	133·25	
" piston speed each engine,	533·00	
" boiler pressure,	123·00	
	Right Engine.	Left Engine
" initial "	105.209	105·743
" cut-off in parts of stroke,	·5142	·5437
" terminal pressure,	42·199	45·180
" release in parts of stroke,	·8558	·8874
" counter pressure at mid stroke,	5·726	6·646

Mean exhaust closure in parts of stroke, .	·2935	·2067
" effective pressure, . . .	62.394	64·005
Grade of expansion including clearance,	2·092	1·979

DISTRIBUTION OF THE LOAD.

Indicated horse-power, . . .	191·623	196·876
	388·502	
Power absorbed by engine above all resistances,	44·276	
Gross load, ...	344·226	
Extra friction due to load, . .	17·211	
Power expended in moving the train, .	327·015	

COST OF THE POWER.

Steam per hour to the engines, . .	12415·09	
Piston displacement per hour to release,	37648·70	39003.18
" " " " exhaust closure,	12911·60	9084·89
Volume of clearance per hour, . .	3343·41	3340·33
Weight of steam accounted for to release per hour,	5660·96	6138·47
" " " retained by cushion per hour,	800·55	670·45
" " " by diagrams, .	4860·41	5468·02
	10324 43	
Percentage of steam accounted for, . ·	83·191	
Steam per indicated horse-power per hour by boiler, ...	31·956	
Steam per indicated horse-power per hour by diagrams, . .	25·364	27·774
	26·569	
Coal per indicated horse-power per hour by actual evaporation, . . .	5·359	
Coal per indicated horse-power per hour 9 to 1,	3·551	
Relative capacity of engines, . .	·9733	1·0000
" economy " " . .	1·0000	·9132

In the engraved diagrams, which by the liberality of the Baldwin Locomotive Works are made a part of this paper, all the original lines have been faithfully copied by Mr. J. Snowden Bell, who reproduced the cards for the engraver: and have been selected with a view to exhibiting graphically the action of the engines under test-trial. The diagrams have been worked together, and are cards of the same series from both engines.

The diagrams are produced in the following order:

TWIN CREEK, No. 1.

Right.

Boiler pressure,	140·
Initial "	135·
Cut-off in fraction of stroke,	·6618
Release " "	·9075
Terminal pressure,	79·50
Counter "	1·125
Exhaust closure,	·1982
Mean effective pressure,	111·190
Revolutions,	51.
Indicated horse-power,	136·157

Left.

Boiler pressure,	140·
Initial "	136·75
Cut-off,	·7000
Release,	·9140
Terminal pressure,	84·687
Counter "	·875
Exhaust closure,	·1331
Mean effective pressure,	112·320
Revolutions,	51.
Indicated horse-power,	137·391

CINCINNATI, No. 24.

Right.

Boiler pressure,	130·
Initial "	123·375
Cut-off in fraction of stroke,	·5580
Release " "	·8901
Terminal pressure,	59·625
Counter "	1·75
Exhaust closure,	·2450
Mean effective pressure,	89·127
Revolutions,	67·51
Indicated horse-power,	144·470

Left.

Boiler pressure,	130·
Initial "	124·125

Cut-off in fraction of stroke,	·6000
Release " "	·9022
Terminal pressure,	62·125
Counter "	2·312
Exhaust closure,	·1824
Mean effective pressure,	92·055
Revolutions,	67·51
Indicated horse-power,	149·083

CINCINNATI, No. 5.

Right.

Boiler pressure,	132·
Initial "	114·375
Cut-off in fraction of stroke,	·4740
Release " "	·8362
Terminal pressure,	43·375
Counter "	1·875
Exhaust closure,	·3304
Mean effective pressure,	70·407
Revolutions,	120·02
Indicated horse-power,	202·894

Left.

Boiler pressure,	132·
Initial "	115·625
Cut-off in fraction of stroke,	·5000
Release " "	·8770
Terminal pressure,	47·937
Counter "	1·875
Exhaust closure,	·2275
Mean effective pressure,	74·064
Revolutions,	120·02
Indicated horse-power,	213·290

CINCINNATI, No. 6.

Right.

Boiler pressure,	129
Initial "	112·375
Cut-off in fraction of stroke,	·3309
Release " "	·8192
Terminal pressure,	32·000

Counter pressure,	2·062
Exhaust closure,	·3761
Mean effective pressure,	52·500
Revolutions,	106·69
Indicated horse-power,	134·490

Left.

Boiler pressure,	129·
Initial "	112 625
Cut-off in fraction of stroke,	·3880
Release " "	·8448
Terminal pressure,	37·000
Counter "	2·000
Exhaust closure,	·3265
Mean effective pressure,	58·208
Revolutions,	106·69
Indicated horse-power,	148·977

HAMILTON, No. 14.

Right.

Boiler pressure,	135·
Initial "	122·344
Cut-off in fraction of stroke,	·3309
Release " "	·8192
Terminal pressure,	33·062
Counter "	10·875
Exhaust closure,	·3761
Mean effective pressure,	45·927
Revolutions,	170·21
Indicated horse-power,	187·698

Left.

Boiler pressure,	135·
Initial "	121·750
Cut-off in fraction of stroke,	·3880
Release " "	·8448
Terminal pressure,	37·250
Counter "	8·437
Exhaust closure,	·3265
Mean effective pressure,	51 794
Revolutions,	170·21
Indicated horse-power,	211·485

CINCINNATI, No. 35.

Right.

Boiler pressure,	98·
Initial "	79 312
Cut-off in fraction of stroke,	·3309
Release " "	·8192
Terminal pressure,	20·312
Counter "	2 875
Exhaust closure,	·3761
Mean effective pressure,	32·420
Revolutions,	208·33
Indicated horse-power,	162·170

Left.

Boiler pressure,	98·
Initial "	76·938
Cut-off in fraction of stroke,	·3880
Release in " " "	·8448
Terminal pressure,	21·375
Counter "	2·750
Exhaust closure,	·3265
Mean effective pressure,	33·936
Revolutions,	208·33
Indicated horse-power,	169·597

The general excellence of the engines from which these diagrams were taken will be apparent to engineers familiar with the indicator; at the same time it should be remembered that the valves were set entirely by the marks on the valve stems and guide bars.

The diagrams would be eminently creditable to many an automatic cut-off engine wherein the admission and cut-off are controlled by one valve or system of valves, and the release and exhaust closure regulated by another valve or system of valves, as in the Corliss engine; as it is, a single D slide valve, operated by a pair of eccentrics and a shifting link, performed all the functions of lead, port-opening, cut-off, release and exhaust closure.

The diagrams are worthy of study and emulation by builders of fixed cut-off engines; for the locomotive is simply a fixed cut-off engine, variable by hand. But so long as fixed cut-off engines are controlled in speed by the present system of governor which, as it were, throttles

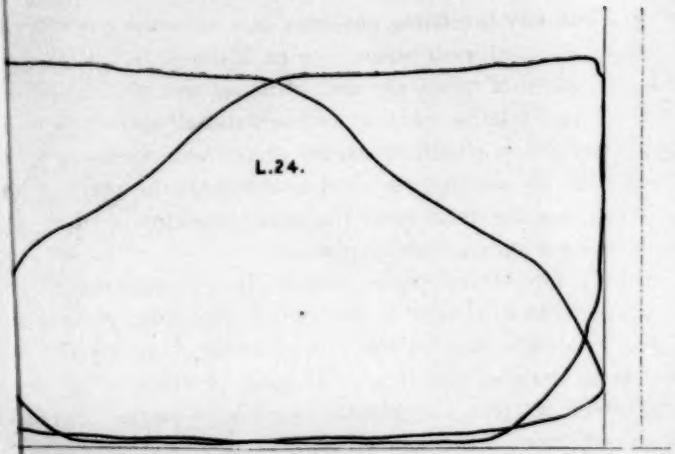
the engine in the act of respiration, but little improvement can be expected in the realized effect of valve motion.

The ordinary throttling governor is a nuisance that should not be tolerated by intelligent steam engine builders, for in the best form it robs the steam of *twenty per cent.* of its *vis viva* in effecting regulation, and the high relative economy of the standard automatic cut-off engine is entirely due to admitting steam at or near the boiler pressure and cutting off the quantity required to overcome the resistance, instead of wire drawing the steam until the mean pressure is equivalent to the resistance per square inch of piston.

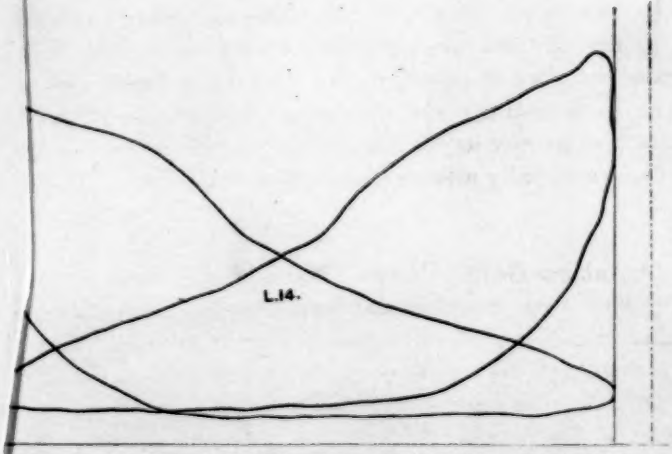
In the locomotive engine, whilst the communication between the steam-dome and cylinder is not as free with early points of cut-off as in the automatic engine, the wire drawing is very much less than in throttling engines; and if a valve gear be devised for lococomotives which will produce a maximum opening of steam port for all points of cut-off; then for equal initial pressures and grades of expansion the economy of the locomotive and automatic engines (size of cylinder and speed of piston considered) would approximate.

For a given speed, given load, and given condition of track, the resistance is represented by a certain mean pressure per square inch of piston for a single stroke or for any number of strokes, with the elements affecting the resistance unchanged; and a nearer approximation of the initial pressure in the cylinder to that of the boiler, reduced friction in the port opening as the steam flows in, steam line declining less to the point of cut-off, earlier cut-off and higher grade of expansion, would improve the economy of performance of the locomotive without impairing its efficiency otherwise. It is possible to do all this without materially altering the existing valve gear.

Imitation Gold.—Messrs. Maffre & Co. make an alloy which resembles gold in color and resistance to oxidation, by melting together in a crucible 800 grammes of pure copper, 25 grammes of platinum, and 10 grammes of tungstinic acid. When thoroughly melted, the mass is granulated by letting it run into water which contains 500 grammes (17·64 oz.) slaked lime, and 500 grammes of potash per cubic metre (35·32 cu. ft.). The granulated alloy is dried, re-melted and 170 grammes (6 oz.) of gold are added and thoroughly incorporated.—*Fortsch. der Zeit.* C.



No. 24. Left Engine. Cincinnati to Hamilton. Rev's, 67·51.



No. 14. Left Engine. Hamilton to Twin Creek. Rev's, 170·21.

whistle. In addition to these losses, the drain-cocks of the cylinders were occasionally opened, and a small quantity of steam was wasted in the attempt to make calorimeter observations. Taking the difference between the water pumped into boiler and steam delivered to the engines at *seven* per cent. of the total quantity, then of this quantity but *ninety-three* per cent. was properly chargeable to the engine.

The per centage of steam accounted for by the indicator becomes

$$\frac{85{\cdot}068}{{\cdot}93} = 91{\cdot}47$$

for the run from Cincinnati to Hamilton;

$$\frac{80{\cdot}271}{{\cdot}93} = 86{\cdot}31$$

for the run from Hamilton to Twin Creek; and

$$\frac{83{\cdot}191}{{\cdot}93} = 89{\cdot}45$$

for the run from Twin Creek to Dayton; and the actual steam per indicated horse-power per hour, became for the three independent runs 30·02 pounds, 31·05 pounds and 29.72 pounds, respectively.

A 16 in. non-condensing Harris-Corliss engine, working at 500′ piston speed, initial pressure of 100 pounds above atmosphere and cutting off at $\frac{2}{10}$ of stroke, would require about 21·5 pounds of water per indicated horse-power per hour.

It has been suggested by an eminent English engineer, that of the total power developed by a locomotive, 25 per cent. was absorbed by the engine itself in overcoming friction and working the pumps. The pumps were on during the run for friction diagrams, and the power expended in this direction is embraced in the second quantity under the distribution ot the load.

During the run from Cincinnati to Hamilton the mean indicated load on the locomotive was 291·958 horse-power, and the mean total friction load 33·384 + 12·929 = 46·313 horse-power, and the percentage of total power absorbed by the engine itself in overcoming all resistances becomes

$$\frac{46{\cdot}313 \times 100}{291{\cdot}958} = 15{\cdot}86.$$

During the run from Hamilton to Twin Creek, the mean indicated load was 368·658 horse-power, and the total friction load was 57·632 horse-power, and percentage of total power absorbed by the engine in overcoming all resistances becomes

1	2	3	4	5
Diagrams.	Boiler Pressure.	Revolutions.	Initial Pressure.	Cut-off.
1	130	48·50	68·075	·70
2	131	57·76	55·187	·70
3	125	74·53	52·000	·70
4	135	102·07	112·125	·47
5	132	120·02	114·375	·47
6	129	106·69	112·375	·33
7	132	103·43	109·812	·33
8	120	104·45	46·375	·33
9	119	104·45	104·000	·33
10	122	104·45	104·187	·47
11	117	112·32	107·625	·47
12	112	96·01	102·475	·47
13	109	105·00	95·562	·53
14	115	80·48	92·688	·53
15	120	69·48	103·750	·53
16	125	69·48	109·000	·53
17	134	69·48	117·750	·53
18	130	68·59	122·937	·53
19	135	77·12	116·988	·53
20	129	77·12	123·437	·53
21	132	67·79	115·937	·53
22	129	75·81	118·937	·53
23	134	73·12	118·000	·53
24	130	67·51	123·375	·53
25	135	67·51	117·500	·53
26	130	67·51	124·187	·53
27	135	71·05	117·187	·53
28	131	71·05	124·375	·53
29	131	81·77	118·651	·66
30	130	81·77	120·125	·66
31	127	113·85	117·437	·53
32	120	208·33	108·875	·53
33	112	208·33	101·500	·53
34	97	208·33	89·567	·33
35	98	208·33	79·312	·33
36	97	170·94	76·125	·33
37	99	155·09	34·875	·33
38	112	139·23	33·750	·33
39	92	78·90	33·000	·33
40	115	61·19	49·750	·33
	122	100·473	97·272	·50
1	125	42·02	114·125	·5
2	120	95·23	110·843	·5
3	123	107·89	108·818	·5
4	130	113·46	114·937	·5
5	125	113·46	105·000	·5
6	120	113·46	103·500	·5
7	118	106·14	104·250	·5
8	128	114·19	114·187	·5
9	130	114·19	109·437	·5
10	122	134·29	105·500	·4
11	116	114·86	99·687	·4
12	128	142·23	110·375	·3
13	130	135·67	107·987	·3
14	135	170·21	122·344	·3
15	132	146·70	107·937	·3
16	130	205·56	111·281	·3
17	120	120·23	98·375	·5
18	115	107·00	97·062	·5
19	114	177·62	92·687	·5
20	115	109·17	94·750	·5
	124	124·179	106·654	·4
1	140	51·00	135·000	·6
2	140	86·46	128·906	·5
3	133	121·83	111·406	·5
4	125	121·83	108·187	·5
5	130	127·47	112·912	·4
6	125	140·89	108·281	·4
7	120	140·89	102·250	·4
8	119	145·32	100·187	·4
9	118	149·38	100·502	·4
10	116	161·55	98·002	·4
11	120	145·50	110·625	·4
12	126	141·65	111·000	·4
13	130	144·53	111·250	·4
14	128	157·30	107·500	·4
15	122	151·90	101·937	·4
16	124	146·58	104·625	·4
17	123	152·97	102·843	·4
18	120	141·86	101·812	·4
19	115	123·10	97·593	·4
20	100	123·10	91·437	·4
21	100	123·10	64·687	·4
	123	133·25	105·289	·4

FROM THE INDICATOR DIAGRAMS.

CINCINNATI TO HAMILTON.

RIGHT ENGINE. LEFT ENGINE.

4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Initial Pressure.	Cut-off.	Release.	Terminal Pressure.	Counter Pressure.	Exhaust Closure.	Mean Effective Pressure.	Indicated Horse-power.	Initial Pressure.	Cut-off.	Release.	Terminal Pressure.	Counter Pressure.	Exhaust Closure.	Mean Effective Pressure.	Indicated Horse-power.	Aggregate Indicated Horse-power.	TRACK.
68·075	·7006	·9331	48·312	0·250	·1119	59·200	69·068	68·812	·7222	·9372	45·468	0·250	·1078	60·442	70·453	139·521	Curve, 1° 00′ def.; cen. angle, 16° 24′. Level.
55·187	·7006	·9331	33·687	0·500	·1119	47·055	65·275	55·750	·7222	·9372	34·500	0·250	·1078	47·412	65·708	130·983	Tangent. "
52·000	·7006	·9331	31·812	0·500	·1119	43·119	77·163	51·093	·7222	·9372	30·125	0·500	·1078	41·981	75·057	152·220	Curve, 1° 30′ def.; cen. angle, 16° 21′. "
112·125	·4740	·8362	40·937	1·250	·3304	66·122	162·050	108·750	·5000	·8770	44·910	2·000	·2275	70·326	172·194	334·244	" 1° 00′ " " 24° 36′. "
114·375	·4740	·8362	43·375	1·875	·3304	70·407	202·894	115·625	·5000	·8770	47·937	1·875	·2275	74·064	233·290	416·184	" 1° 00′ " " 11° 30′. "
112·375	·3309	·8192	32·000	2·062	·3761	52·500	134·490	112·625	·3880	·8448	37·000	2·000	·3265	58·208	148·977	283·467	" 1° 30′ " " 33° 02′. "
109·812	·3309	·8192	28·062	2·125	·3761	50·553	125·545	110·437	·3880	·8448	34·437	2·125	·3265	55·118	136·757	262·302	" 1° 45′ " " 49° 09′. "
46·375	·3309	·8192	10·031	0·875	·3761	17·577	44·079	95·437	·3880	·8448	27·312	1·000	·3265	46·567	116·675	160·754	Tangent. Up grade, 1·910.
104·000	·3309	·8192	28·750	2·375	·3761	48·542	121·733	101·000	·3880	·8448	29·750	0·500	·3265	51·543	129·142	250·875	" " "
104·187	·4740	·8362	37·687	2·125	·3304	60·346	151·335	104·187	·5000	·8770	39·312	2·875	·2275	62·389	156·318	307·653	" " "
107·625	·4740	·8362	40·000	2·375	·3304	63·585	171·482	108·750	·5000	·8770	42·650	3·062	·2275	66·902	180·204	351·746	" " 1·651.
102·475	·4740	·8362	37·500	2·000	·3304	59·037	136·097	103·875	·5000	·8770	37·968	2·750	·2275	61·146	140·828	276·925	Curve, 0° 30′ def.; cen. angle, 6° 00′. Level.
95·562	·5580	·8901	43·000	2·500	·2450	64·347	162·229	95·562	·6000	·9022	44·437	4·875	·1824	64·764	163·128	325·357	Tangent. Up grade, 1·376.
92·688	·5580	·8901	42·312	2·875	·2450	62·878	121·503	93·375	·6000	·9022	43·093	5·000	·1824	62·735	121·118	242·621	" " 1·390.
103·750	·5580	·8901	48·750	1·750	·2450	73·255	122·208	103·750	·6000	·9022	49·437	2·000	·1824	75·133	125·227	247·435	" " "
109·000	·5580	·8901	51·937	1·750	·2450	78·028	130·169	110·625	·6000	·9022	54·125	2·500	·1824	80·768	134·620	264·789	" " "
117·750	·5580	·8901	58·687	1·875	·2450	85·339	142·367	118·406	·6000	·9022	59·625	2·250	·1824	87·822	146·378	288·745	Curve, 1° 00′ def.; cen. angle, 32° 11′. Up grade, 1·250.
122·937	·5580	·8901	58·500	1·500	·2450	89·211	146·923	123·843	·6000	·9022	62·187	2·312	·1824	91·415	150·415	297·338	" " " " "
116·688	·5580	·8901	57·500	1·375	·2450	86·238	159·687	118·093	·6000	·9022	57·875	1·937	·1824	87·216	161·354	321·041	Tangent. Up grade, 1·283.
123·437	·5580	·8901	62·562	1·750	·2450	90·523	167·621	125·125	·6000	·9022	63·312	1·937	·1824	93·440	172·866	340·487	" " "
115·937	·5580	·8901	57·500	1·750	·2450	85·027	138·398	118·500	·6000	·9022	59·125	2·250	·1824	87·392	142·606	281·004	" " 1·260.
118·937	·5580	·8901	58·625	1·750	·2450	85·988	156·520	120·437	·6000	·9022	59·312	2·500	·1824	88·848	161·580	318·100	Curve, 0° 45′ def.; cen. angle, 21° 11′. " 1·256.
118·000	·5580	·8901	58·625	1·500	·2450	86·413	151·712	118·468	·6000	·9022	58·468	2·750	·1824	87·433	153·364	305·076	" " " " " " " "
123·375	·5580	·8901	59·625	1·750	·2450	89·127	144·470	124·125	·6000	·9022	62·125	2·312	·1824	92·055	149·083	293·553	" 1° 00′ " " 14° 30′. " 1·250.
117·500	·5580	·8901	57·031	2·000	·2450	86·413	140·071	118·500	·6000	·9022	60·000	2·250	·1824	87·965	142·459	282·530	Tangent. " 1·278.
124·187	·5580	·8901	63·187	1·500	·2450	91·924	149·004	125·625	·6000	·9022	64·437	2·062	·1824	93·274	151·056	300·060	" " "
117·187	·5580	·8901	57·500	1·875	·2450	84·576	144·284	118·125	·6000	·9022	58·750	2·375	·1824	85·664	146·006	290·290	Curve, 0° 45′ def.; cen. angle, 39° 00′. " 1·248.
124·375	·5580	·8901	61·500	2·000	·2450	91·924	156·819	125·687	·6000	·9022	62·500	2·250	·1824	93·460	159·257	316·076	" " " " " " " "
118·651	·6618	·9075	67·250	2·062	·1982	94·635	185·801	120·437	·7000	·9140	64·875	2·937	·1331	95·235	186·867	372·668	" " " " " " " "
120·125	·6618	·9075	70·312	1·625	·1982	97·084	190·611	120·468	·7000	·9140	69·000	2·375	·1331	97·433	191·121	381·732	Tangent. Level.
117·437	·5580	·8901	58·375	2·062	·2450	84·716	231·584	118·812	·6000	·9022	59·062	3·125	·1824	86·105	235·163	466·747	Curve, 1° 00′ def.; cen. angle, 24° 20′. Up grade, 1·209.
108·875	·5580	·8901	51·875	6·687	·2450	72·348	361·892	108·812	·6000	·9022	53·187	8·687	·1824	72·845	364·049	725·941	Tangent. Down grade, 1·5227.
101·500	·5580	·8901	47·562	4·250	·2450	69·767	338·984	103·187	·6000	·9022	49·875	4·750	·1824	72·458	362·117	701·101	" " 1·270.
89·567	·3309	·8192	21·500	2·500	·3761	36·830	184·231	88·125	·3880	·8448	25·375	3·125	·3265	40·326	201·534	385·765	" " 1·345.
79·312	·3309	·8192	20·312	2·875	·3761	32·420	162·170	76·938	·3880	·8448	21·375	2·750	·3265	33·936	169·597	331·767	" " "
76·125	·3309	·8192	17·500	5·000	·3761	27·665	113·548	78·500	·3880	·8448	21·375	4·500	·3265	31·842	130·575	244·123	Curve, 1° 00′ def.; cen. angle, 27° 18′. " 1·455.
34·875	·3309	·8192	6·375	3·375	·3761	6·705	24·968	64·000	·3880	·8448	16·250	4·250	·3265	23·265	86·556	111·524	Tangent. " 1·625.
33·750	·3309	·8192	6·093	2·937	·3761	5·759	19·252	35·250	·3880	·8448	6·250	2·875	·3265	8·596	28·710	47·962	" " 1·2694.
33·000	·3309	·8192	4·875	2·000	·3761	7·586	14·371	34·125	·3880	·8448	7·000	3·500	·3265	8·596	16·270	30·641	" " "
49·750	·5580	·8901	20·875	1·062	·2450	33·139	48·689	49·250	·6000	·9022	20·625	2·500	·1824	32·937	48·348	97·037	" Level.
97·272	·5066	·8695	42·547	2·106	·2736	63·447	141·782	99·812	·5486	·8879	44·610	2·653	·2160	66·484	150·175	291.958	

HAMILTON TO TWIN CREEK.

114·125	·5580	·8901	55·531	1·000	·2450	83·477	84·222	107·437	·6000	·9022	63·187	4·000	·1824	87·514	88·214	172·436	Tangent. Level.
110·843	·5580	·8901	50·000	2·250	·2450	73·731	168·589	106·031	·6000	·9022	56·087	3·000	·1824	76·852	175·565	344·154	Curve, 1° 00′ def.; cen. angle, 18° 15′. "
108·818	·5580	·8901	50·250	4·625	·2450	72·937	188·947	109·062	·6000	·9022	56·125	5·000	·1824	76·991	199·264	388·211	Tangent. Up grade, 1·644.
114·937	·5580	·8901	54·312	6·062	·2450	77·216	210·358	112·937	·6000	·9022	58·062	7·000	·1824	79·597	216·645	427·003	" " "
105·000	·5580	·8901	48·250	4·562	·2450	69·913	190·462	106·000	·6000	·9022	52·125	7·375	·1824	72·705	197·888	388·350	" " "
103·500	·5580	·8901	49·625	3·656	·2450	71·942	195·988	114·562	·6000	·9022	52·062	4·531	·1824	73·233	199·324	395·312	" " "
104·250	·5580	·8901	50·562	2·500	·2450	72·138	183·844	104·750	·6000	·9022	51·125	3·500	·1824	74·466	189·605	373·449	" " 1·339.
114·187	·5580	·8901	55·218	4·187	·2450	79·186	217·110	114·781	·6000	·9022	57·187	5·687	·1824	80·443	220·358	437·468	Curve, 1° 00′ def.; cen. angle, 22° 30′. " 1·11023.
109·437	·5580	·8901	57·000	6·375	·2450	72·297	198·225	108·125	·6000	·9022	51·375	6·750	·1824	73·274	200·719	398·944	Tangent. " 1·931.
105·500	·4740	·8362	37·437	5·000	·3304	57·308	184·786	107·437	·5000	·8770	41·000	6·375	·2275	60·088	193·572	378·358	" " 1·1124.
99·687	·4740	·8362	34·375	4·687	·3304	54·051	149·066	101·437	·5000	·8770	37·875	6·250	·2275	55·941	154·138	303·204	" " "
110·375	·3309	·8192	28·875	4·000	·3761	48·554	165·813	111·500	·3880	·8448	34·625	4·500	·3265	52·058	177·619	343·432	" Down grade, 1·384.
107·987	·3309	·8192	30·525	7·750	·3761	44·861	146·136	114·937	·3880	·8448	34·250	7·875	·3265	48·705	158·574	304·710	" " 1·789.
122·344	·3309	·8192	33·062	10·875	·3761	45·927	187·698	121·750	·3880	·8448	37·250	8·437	·3265	51·794	211·485	399·183	" Up grade, 1·1625.
107·937	·3309	·8192	28·187	5·625	·3761	43·699	153·925	108·687	·3880	·8448	33·750	5·937	·3265	49·661	174·767	328·692	" " 1·1750.
111·281	·3309	·8192	29·750	5·812	·3761	45·519	224·667	113·125	·3880	·8448	33·875	6·250	·3265	51·088	251·924	476·591	Curve, 0° 50′ def.; cen. angle, 40° 00′. Tangent. Level.
98·375	·5580	·8901	44·562	7·093	·2450	61·740	178·258	99·000	·6000	·9022	48·312	8·062	·1824	65·478	188·857	367·115	Curve, 0° 50′ def.; cen. angle, 40° 00′. Up grade, 1·495.
97·062	·5580	·8901	43·937	6·500	·2450	61·662	171·265	97·812	·6000	·9022	46·500	7·937	·1824	64·853	166·465	337·730	Tangent. " 1·534.
92·687	·5580	·8901	41·250	8·437	·2450	55·947	238·695	94·687	·6000	·9022	44·437	9·500	·1824	59·647	254·149	492·754	" Down grade, 1·2230.
94·750	·5580	·8901	41·375	8·125	·2450	58·789	154·102	96·637	·6000	·9022	46·250	9·000	·1824	61·852	161·983	316·085	" Up grade, 1·534.
106·654	·4028	·8689	43·204	5·495	·2861	62·545	179·693	107·538	·5170	·8853	46·773	6·353	·2229	65·812	189·055	368·659	

TWIN CREEK TO DAYTON.

135·000	·6618	·9075	79·500	1·125	·1982	111·190	136·157	136·750	·7000	·9140	84·687	0·875	·1331	112·320	137·391	273·548	Tangent. Up grade, 1·976.
128·906	·5580	·8901	66·500	2·750	·2450	93·082	193·232	130·000	·6000	·9022	68·875	2·750	·1824	96·174	199·471	392·703	" " "
111·406	·5580	·8901	51·750	6·625	·2450	72·870	213·162	111·687	·6000	·9022	56·218	6·500	·1824	76·588	223·836	436·998	" " "
108·187	·5580	·8901	50·343	6·500	·2450	71·129	208·070	107·750	·6000	·9022	53·062	6·031	·1824	74·117	216·610	424·680	" " "
112·912	·4740	·8362	41·687	4·250	·3304	63·295	193·722	111·875	·5000	·8770	45·375	5·500	·2275	65·885	201·465	395·187	" " 1·540.
108·281	·4740	·8362	38·685	5·500	·3304	58·616	198·289	110·468	·5000	·8770	41·937	7·250	·2275	61·574	208·108	406·397	Curve, 1° 00′ def.; cen. angle, 38° 00′. Level.
102·250	·4740	·8362	35·000	6·000	·3304	52·069	176·145	103·125	·5000	·8770	37·937	7·375	·2275	54·839	185·344	361·489	Tangent. Up grade, 1·2761.
100·187	·4740	·8362	34·427	6·000	·3304	53·103	185·289	102·812	·5000	·8770	38·593	7·937	·2275	54·816	191·092	376·381	Curve, 1° 00′ def.; cen. angle, 41° 00′. Level.
100·562	·4740	·8362	34·250	6·500	·3304	53·448	191·707	100·250	·5000	·8770	40·062	8·437	·2275	55·478	198·806	390·513	" 1° 02′ " " 43° 08′. "
98·062	·4740	·8362	33·000	6·000	·3304	52·758	204·644	101·187	·5000	·8770	37·937	7·718	·2275	53·735	208·242	412·886	Tangent. Up grade, 1·3491.
110·625	·4740	·8362	38·625	7·250	·3304	59·820	208·967	106·250	·5000	·8770	40·312	7·625	·2275	57·631	201·154	410·441	" " "
111·000	·4740	·8362	39·000	7·375	·3304	61·642	209·652	113·188	·5000	·8770	42·375	7·125	·2275	62·991	214·047	423·699	" " 1·978.
111·250	·4740	·8362	38·937	7·000	·3304	60·091	210·300	113·593	·5000	·8770	43·500	7·875	·2275	63·167	219·008	429·308	" " "
107·500	·4740	·8362	37·937	8·187	·3304	57·421	216·875	110·906	·5000	·8770	42·812	8·156	·2275	59·564	224·745	441·620	" " 1·1096.
101·937	·4740	·8362	35·250	8·125	·3304	51·883	189·230	104·843	·5000	·8770	38·031	8·812	·2275	54·227	197·598	386·828	" Level.
104·625	·4740	·8362	37·012	7·625	·3304	54·655	192·357	109·687	·5000	·8770	41·250	7·437	·2275	60·088	211·285	403·642	Curve, 1° 30′ def.; cen. angle, 91° 52′. Up grade, 1·594.
102·843	·4740	·8362	36·000	7·812	·3304	52·922	191·073	106·656	·5000	·8770	39·250	8·437	·2275	57·368	210·518	401·591	" 1° 00′ " " 28° 30′. " 1·2850.
101·812	·4740	·8362	35·000	6·937	·3304	51·919	176·843	104·375	·5000	·8770	38·750	7·812	·2275	56·842	193·437	370·280	Tangent. " 1·842.
97·593	·4740	·8362	33·625	7, 125	·3304	50·517	149·313	99·875	·5000	·8770	36·687	6·937	·2275	54·882	162·069	311·382	Curve, 1° 00′ def.; cen. angle, 14° 24′. " 1·900.
91·437	·6530	·9187	49·656	1·062	·1633	73·119	216·122	92·750	·6950	·9228	55·500	1·750	·1404	76·431	225·647	441·769	Tangent. " 1·1057.
64·687	·7006	·9331	40·000	0·500	·1119	55·122	162·925	42·875	·7222	·9372	25·625	1·250	·1078	35·414	104·577	267·502	" " "
105·289	·5142	·8558	42·199	5·726	·2935	62·394	191·623	105·743	·5437	·8874	45·180	6·646	·2067	64·905	196·876	388·502	

the engine in the act of respiration, but little improvement can be expected in the realized effect of valve motion.

The ordinary throttling governor is a nuisance that should not be tolerated by intelligent steam engine builders, for in the best form it robs the steam of *twenty per cent.* of its *vis viva* in effecting regulation, and the high relative economy of the standard automatic cut-off engine is entirely due to admitting steam at or near the boiler pressure and cutting off the quantity required to overcome the resistance, instead of wire drawing the steam until the mean pressure is equivalent to the resistance per square inch of piston.

In the locomotive engine, whilst the communication between the steam-dome and cylinder is not as free with early points of cut-off as in the automatic engine, the wire drawing is very much less than in throttling engines; and if a valve gear be devised for lococomotives which will produce a maximum opening of steam port for all points of cut-off; then for equal initial pressures and grades of expansion the economy of the locomotive and automatic engines (size of cylinder and speed of piston considered) would approximate.

For a given speed, given load, and given condition of track, the resistance is represented by a certain mean pressure per square inch of piston for a single stroke or for any number of strokes, with the elements affecting the resistance unchanged; and a nearer approximation of the initial pressure in the cylinder to that of the boiler, reduced friction in the port opening as the steam flows in, steam line declining less to the point of cut-off, earlier cut-off and higher grade of expansion, would improve the economy of performance of the locomotive without impairing its efficiency otherwise. It is possible to do all this without materially altering the existing valve gear

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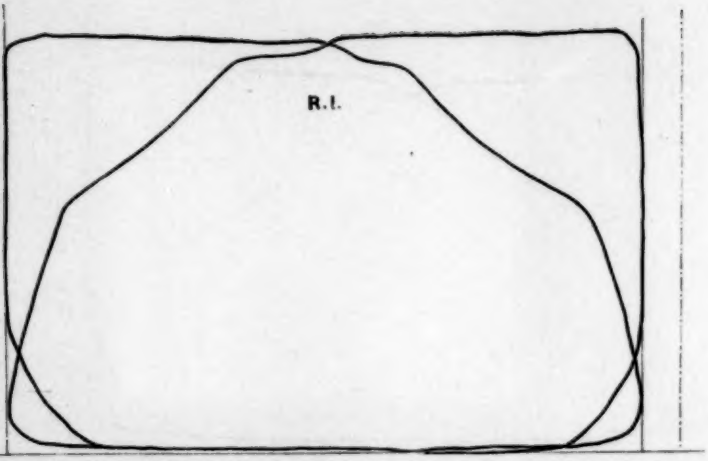
Imitation Gold.—Messrs. Maffre & Co. make an alloy which resembles gold in color and resistance to oxidation, by melting together in a crucible 800 grammes of pure copper, 25 grammes of platinum, and 10 grammes of tungstinic acid. When thoroughly melted, the mass is granulated by letting it run into water which contains 500 grammes (17·64 oz.) slaked lime, and 500 grammes of potash per cubic metre (35·32 cu. ft.). The granulated alloy is dried, re-melted and 170 grammes (6 oz.) of gold are added and thoroughly incorporated.—*Fortsch. der Zeit.* C.

Diagrams No. 1.

Diagrams No. 6.



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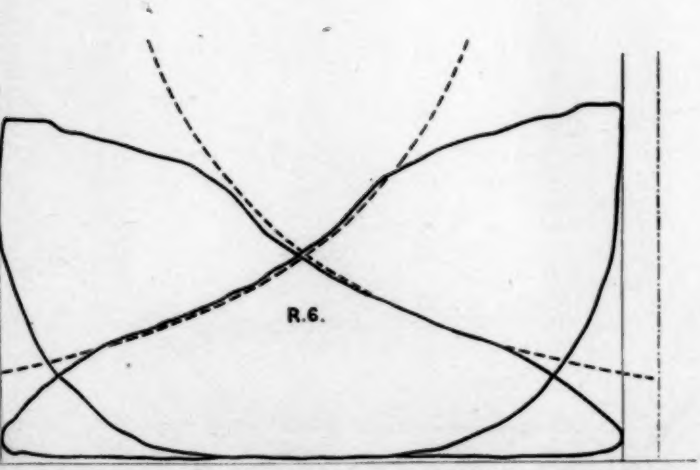

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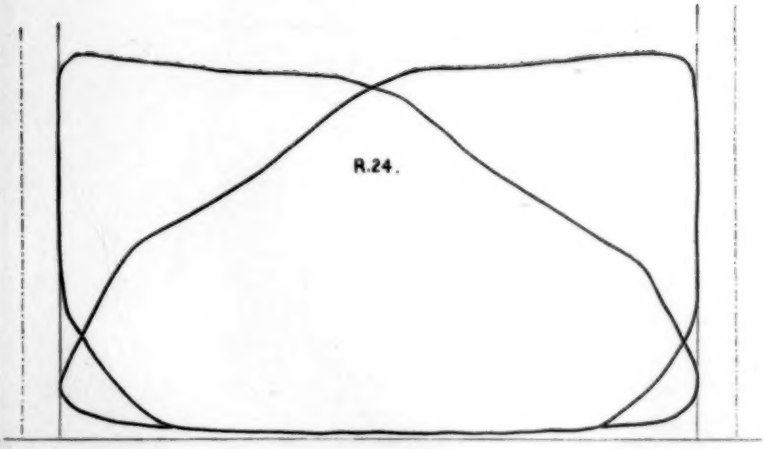

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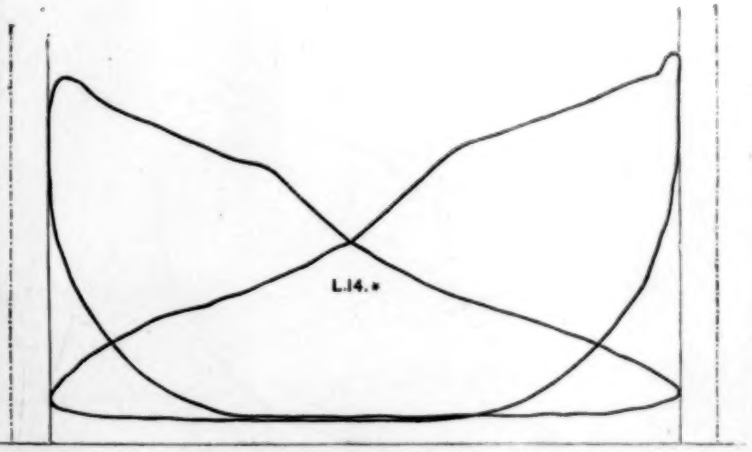
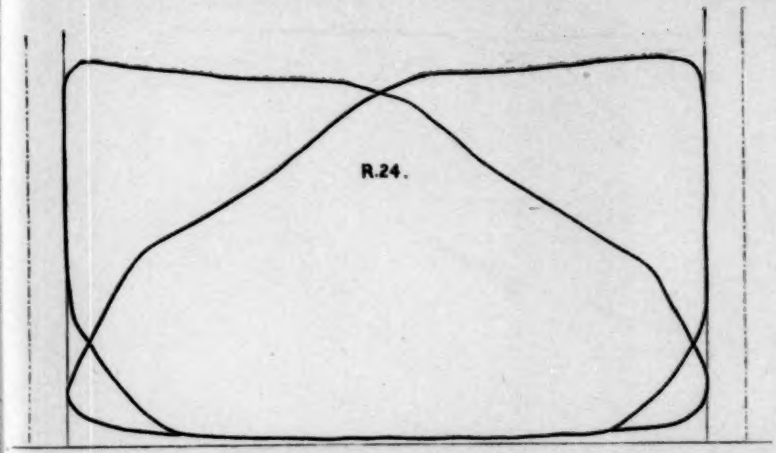


Diagrams No. 14. Right Engine. Hamilton to Twin Creek. Rev's, 170·21.



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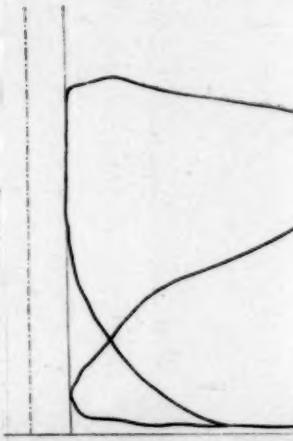

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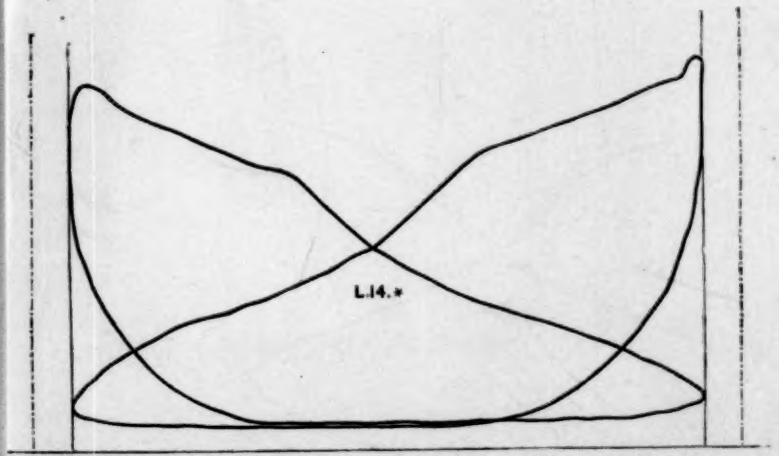

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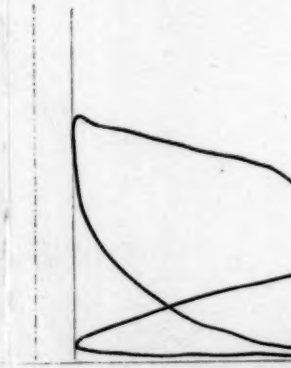

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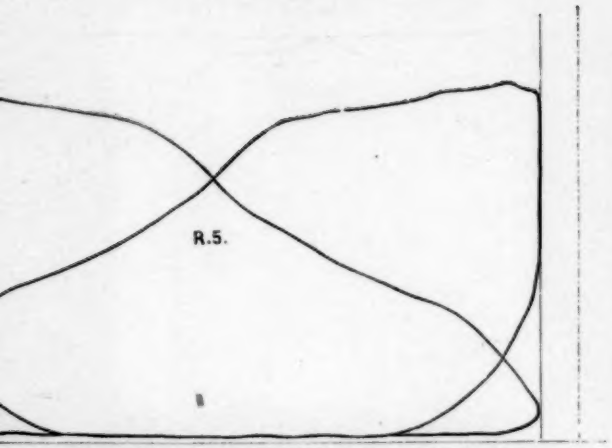
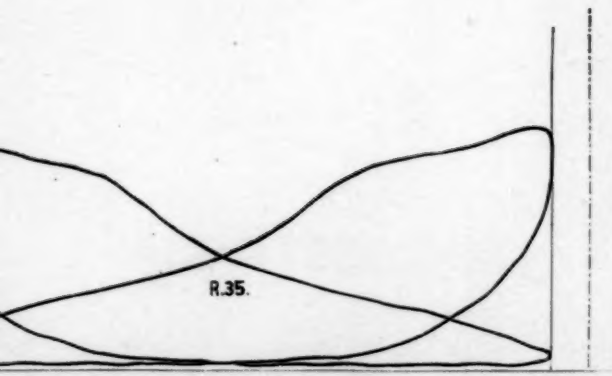
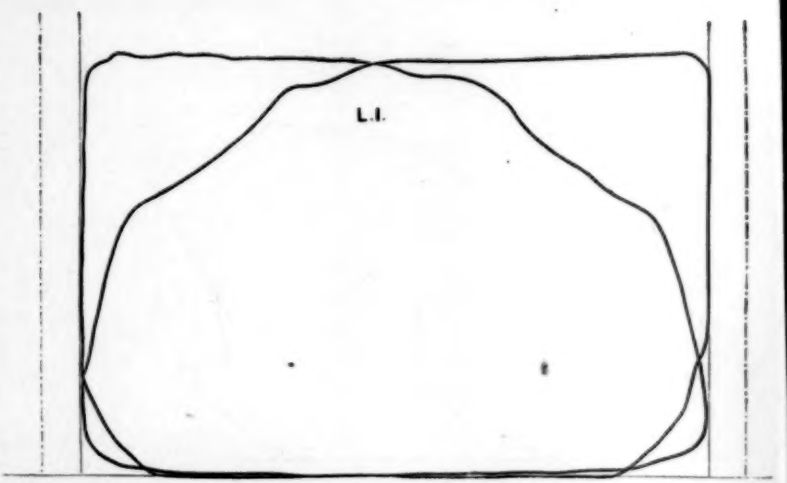


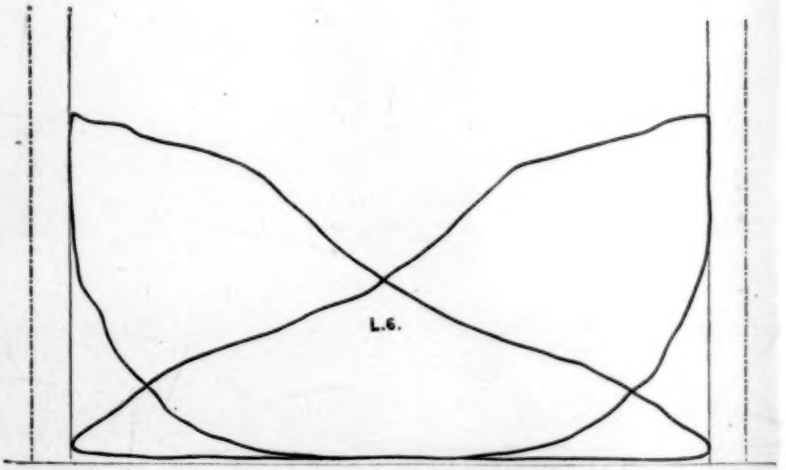
5. Right Engine. Cincinnati to Hamilton. Rev's, 120·02.



35. Right Engine. Cincinnati to Hamilton. Rev's, 208·33.



Diagrams No. 1. Left Engine. Twin Creek to Dayton. Rev's, 51·00.



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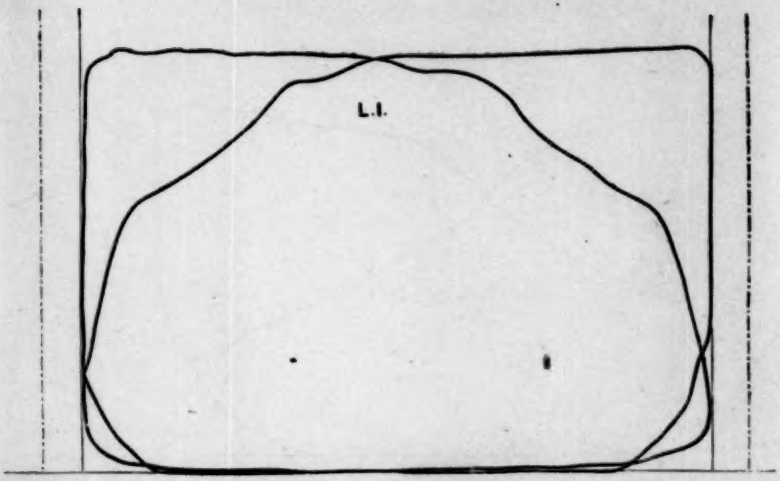

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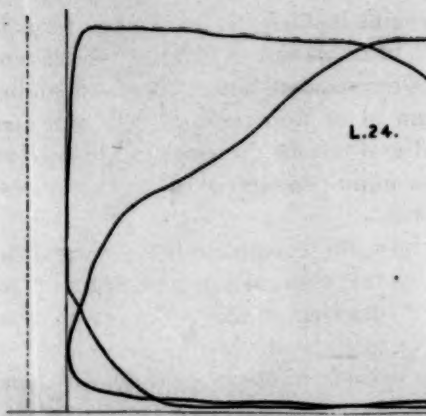

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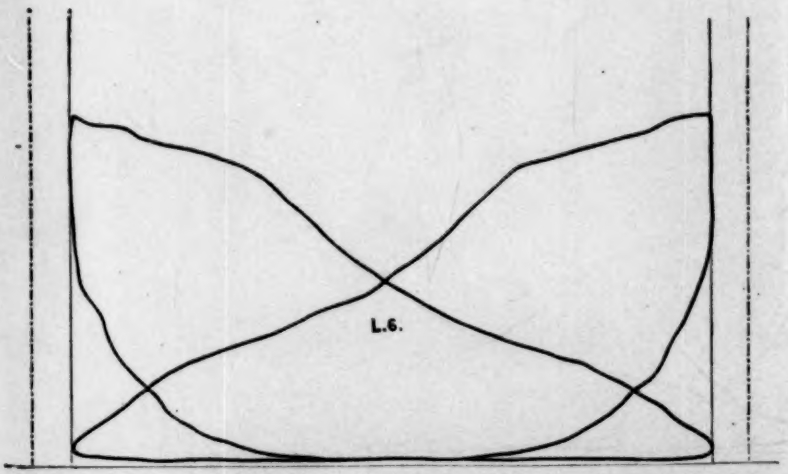

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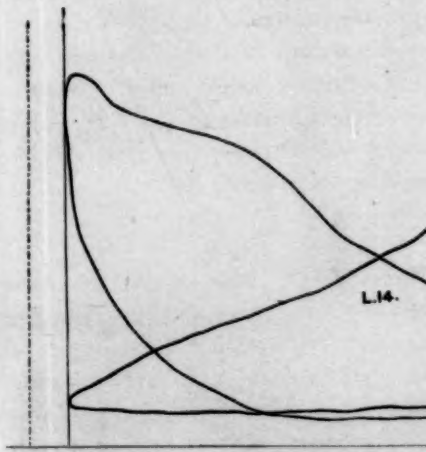

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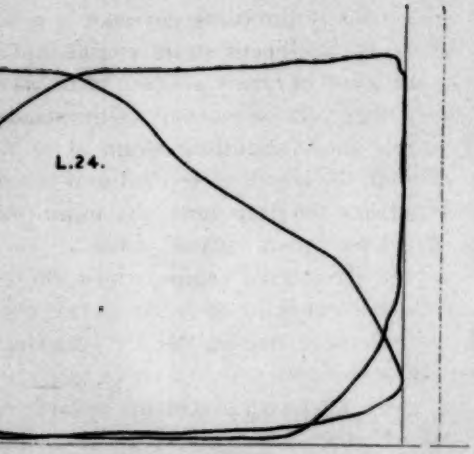
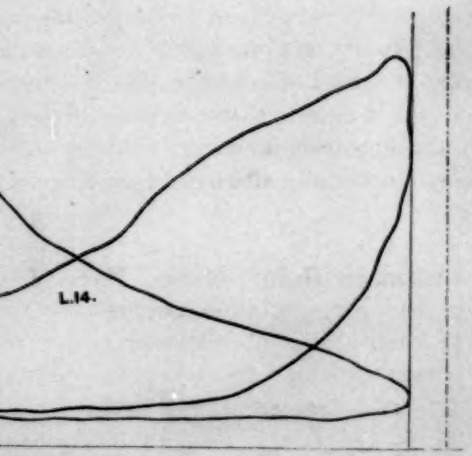
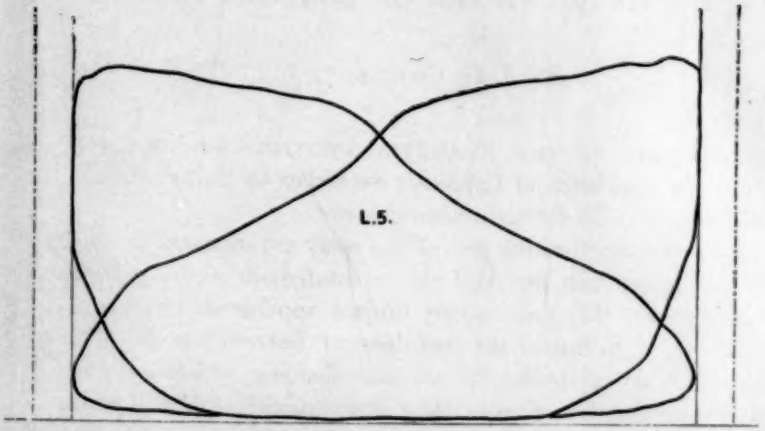


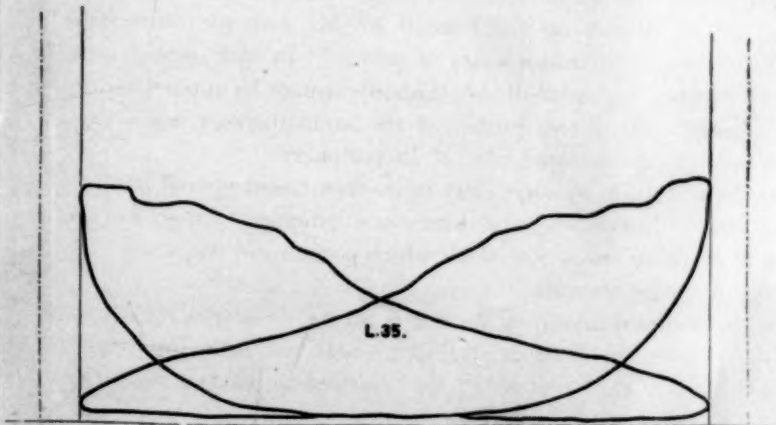
gine. Cincinnati to Hamilton. Rev's, 67·51.



ne. Hamilton to Twin Creek. Rev's, 170·21.



Diagrams No. 5. Left Engine. Cincinnati to Hamilton. Rev's, 120·02.



Diagrams No. 35. Left Engine. Cincinnati to Hamilton. Rev's, 208·33.

ON THE DRIVING POWER OF LEATHER BELTS.

By J. H. Cooper.

In the Journal of the Franklin Institute for November, 1878, is given a translation of Laborde's researches on the principle of the employment of belts for transmitting power.

The rules and tables forming part of this essay are restricted to driving belts which embrace but half the circumference of the pulleys, and for this reason they have a very limited application in practice. In order, therefore, to extend the usefulness of Laborde's work to the calculations of belts on pulleys of unequal diameter, which comprise much the greater number of cases, the "observations" of Mr. J. Heilmann are given below, a manuscript copy of which was kindly furnished to the writer by Mr. V. Steinlen, of Mulhouse.

"Observations on the friction of Belts upon the surface of pulleys and upon the width to give to Belts in special cases; communicated to the Industrial Society at the general meeting, May 27th, 1835, by Mr. Paul Heilmann, former student of the Polytechnic School.

"At the general meeting of the society, held on the 29th of May, 1833, Mr. Joshua Heilmann made you, in the name of the Committee on Mechanics, a report on the memoir of Mr. Laborde concerning the width of belts for transmission of power. In this report it is demonstrated that the table of Mr. Laborde cannot be applied except to the especial case of two pulleys of the same diameter, and consequently each one is enveloped half of its periphery.

"The inquiry made by the society in its department proved in effect that for such a special case the dimensions indicated by the table are good; but in other cases, and those which occur most frequently, the table will no longer answer.

"Having occupied myself in the search for the true laws relating to this theory, as yet but little applied in the arts, and believing to have solved the question, I arrived at the conclusions which I have the honor to submit to the society.

"Before speaking of the width of the belt it is necessary to consider and to study the friction of the belt upon the surface of the pulley; and to find the true expression of this friction we must necessarily

consider the case of a pulley invariably fixed, and with the belt only movable; then admit that there be applied to the belt in the direction of its axis on the one side a force equal to the resistance and on the opposite side a force equal to the true motive power.

"In this manner we shall have the friction at the circumference, while if we had supposed the pulley movable on its axis, the results would only have shown the friction at the centre, arising from the pressure of the belt transmitted to the pulley.

"The science of applied mechanics gives the formula relating to this subject as follows: Calling

P, the resistance to be overcome,
e, the base of Naperian logarithms,
f, the coefficient of friction of leather upon cast iron,
R, the radius of the pulley,
S, the length of the arc of contact,

"This formula is written thus:

$$\text{Friction} = P\left((e)^{\frac{f\,S}{R}} - 1\right)$$

"In considering this formula it is easy to see that the friction diminishes rapidly when the radius increases, and that it augments rapidly with the length of the arc of contact, which explains a fact well known in practice.

"But it is to be noticed that the ratio $\frac{S}{R}$ is a constant quantity for the same angle, whatever may be the radius of the pulley, because the circumferences and consequently the arcs of a same number of degrees are proportional to their radii. It results, therefore, that the friction is the same for the same angle of contact whatever may be the radius of the pulley; or, in other words, that the length of the arc of contact should be proportional to the radius of the pulley to produce the same friction, all the rest being equal. A result of great simplicity.

"All this being considered, we see that the laws concerning the friction of curved surfaces are very different from those which relate to plane surfaces.

"Thus for plane surfaces the ratio of friction to the pressure is constant, whatever may be the extent of the surface, while with the cylindrical surfaces of which we speak, on the contrary, the ratio varies not with the extent of the surface, but with the proportional part of the

circumference—with the number of degrees comprised in the arc of contact.

"It is easy to account for this difference.

"A plane surface under pressure is increased in size, the elements of surfaces which are added are all alike, and what is more important, are all equally pressed over the entire extent of the surface, each inch square, for example, receiving the same pressure.

"But let us consider a cylindrical surface pressed by a belt in the direction of pressure perpendicular to the axis, the pressure is not uniform; it is a maximum at that point where the tension of the belt is a maximum, since it is always the sum of the components in the direction of the radii of the tensions of the adjoining elements.

"This pressure diminishes towards the two extremities, and if an element of surface be added to the arc of contact the pressure will have another distribution on the surface, and the friction will change.

"This reasoning is not applicable to the case where the surface of the belt is increased in the direction of its width, because then any section whatever perpendicular to the length of the belt receives always the same pressure as before.

"It follows then, that:—

"The friction is the same for a same angle and a same tension, whatever may be the width of the belt.

"We see then, that the friction of a belt upon a pulley depends

1st. On the pressure or on the tension of a belt.

2d. On the angle of contact.

"And that the friction is independent

1st. Of the diameter of the pulley.

2d. Of the width of the belt.

"The friction is proportional to the pressure.

"According to the formula cited above I have constructed, with the aid of logarithms the following table, which gives the ratio of friction to pressure for any angle.

"The ratio of friction to pressure for leather upon plane surfaces of cast iron have been taken from the experiments of Mr. Morin; I have, however, verified the figures with a belt such as is in use in cotton mills.

"All the results relate to the cases where the machine passes from a state of rest to that of motion, the case in which the maximum of force is necessary.

"Now let us examine what part the breadth of the belt plays under these circumstances. It is evident after what has been said that the smaller the angle of contact is, the greater the strain which must be put upon the belt to transmit a given force; because the force it is possible to transmit by the pulley is always inferior, or at the most, equal to the friction produced upon the surface; if the resistance of the machine were greater, the belt would slip on the pulley. Now here the width of the belt serves no other purpose but to give to the belt a resistance—a strength sufficient to sustain this tension without stretching or breaking.

"This tension, and with it the width of the belt, must necessarily be in inverse ratio to the figures presented in my table. Consequently, in practice, we must employ the table of Mr. Laborde in the following manner, modified by what I have the honor to present, a method by which one can convince himself that the widths indicated by Mr. Laborde may sometimes be increased in a tenfold proportion, or be reduced to a third, according to circumstances.

"In the first place, in practice, we should determine the number of man- or horse-power, the maximum force to be transmitted by the belt and the speed at which it is to be driven, which will indicate a certain breadth in inches given by the table of Mr. Laborde. Then measure, in degrees, on the surface of the smaller pulley, *i. e.*, the least enveloped, the arc of contact with the belt. Then find in my table the figure which expresses the ratio of friction to the pressure corresponding to an angle of 180°, which served as the basis of construction of Mr. Laborde's table; then multiply the breadth found by this figure, and divide the product by the ratio of friction to the pressure corresponding to the angle of contact found.

"Example: Required, the width of belt to transmit a force of 2 horse-power with a speed of 500 feet per minute, the angle of contact of the smaller pulley being 120°.

"I find in the table of Mr. Laborde 6 inches, which I multiply by $\frac{4670}{2911}$; I have then 9 inches and 7 lines.

"Example: 3 man-power, speed 400 feet per minute, angle 240°. I find 1 inch and 9 lines, which I multiply by $\frac{4670}{6669}$, and I have for the result 1 inch and 3 lines.

"I will add, however, that one must not forget that the weight of the belt and its friction when it is crossed are also factors to be introduced into the formula, if rigorous exactness is to be attained. How-

ever, it is easy to see that their figure is too small to embarrass the practical mechanic, who in all cases should not hesitate to give an excess to the width above that which proceeds from the calculations here given.

Degrees.	Fraction of the Circumference.	Ratio of Friction to the Pressure.	Degrees.	Fraction of the Circumference.	Ratio of Friction to the Pressure.
30	$\frac{1}{12}$	0·0660	22½	$\frac{1}{16}$	0·0491
60	$\frac{2}{12}$	0·1363	45	$\frac{2}{16}$	0·1005
90	$\frac{3}{12}$	0·2112	67½	$\frac{3}{16}$	0·1545
120	$\frac{4}{12}$	0·2911	112½	$\frac{5}{16}$	0·2706
150	$\frac{5}{12}$	0·3763	135	$\frac{6}{16}$	0·3330
180	$\frac{6}{12}$	0·4670	157½	$\frac{7}{16}$	0·3933
210	$\frac{7}{12}$	0·5674	202½	$\frac{9}{16}$	0·5390
240	$\frac{8}{12}$	0·6669	225	$\frac{10}{16}$	0·6145
270	$\frac{9}{12}$	0·7769	247½	$\frac{11}{16}$	0·6937
300	$\frac{10}{12}$	0·8941	292½	$\frac{13}{16}$	0·8642
330	$\frac{11}{12}$	1·0190	315	$\frac{14}{16}$	0·9551
360	$\frac{12}{12}$	1·1522	337½	$\frac{15}{16}$	1·0515

New Voltaic Battery.—M. A. Heraud uses chlorohydrate of ammonia and calomel. When the circuit is closed the chlorohydrate of ammonia, in the presence of zinc, forms a chloride of zinc with the transference of ammonia and hydrogen to the positive electrode. The hydrogen reduces the calomel, yielding metallic mercury, chlorohydric acid, and consequently chlorohydrate of ammonia. As long as there remains any of the calomel about the positive electrode the chlorohydrate of ammonia will be regenerated. In a battery of nine elements the intensity was ·73 at the end of 227 days, and ·50 at the end of 984 days, the primitive intensity being 1. When compared to sulphate of copper the mercury gave an intensity of 1·4512 at the beginning, and 1·0749 after six months' use.—*Comptes Rendus.* C.

ON THE ACTION OF FATTY MATTER IN STEAM-BOILERS.

By G. Pereyra, Mining Engineer.

Translated from the *Annales des Mines* of 1878, by Chief Engineer Isherwood, U. S. Navy.

For many years past the water of condensation of the exhaust steam from steam-engines has been used for feeding boilers. The practice, though possessing advantages, among which is economy of fuel, is not without drawbacks, for numerous accidents have attended it, which have been attributed to the fatty matter contained in this water of condensation.

The practice may be divided into the two cases of the exclusive use of the water of condensation, and of the use of that water mixed with spring or river water. The first has been made the subject of a recent communication from Mr. Hétet to the Academy. That scientific chemist points out deep corrosions of the boiler and the formation of black dense deposits, mixed with oxide of iron, which adhered strongly to the metal and caused it to be overheated or burned. He also points out that this corrosion and its resulting accidents could be avoided by neutralizing with lime the fatty acids contained in the feed-water. The process is excellent, but only on the condition that the water thus treated is separated afterwards by decantation or better still, by filtration from the lime-soap thus formed. The facts to be given in this paper will be found to fully justify this condition.

The mixing of the water of condensation with spring or river water causes greasy-lime deposits, whose effects on boilers are still the subject of numerous controversies. Some engineers deny the injurious influence of these deposits, considering them no worse than ordinary scale; while others attribute to them the most pernicious action. Another class entertains the intermediate opinion, that in certain cases and with certain kinds of water, fatty matter in the boiler can be productive of serious damage.

I am of this latter opinion, for observed facts show both the former ones to be too absolute. But in what cases, and with what waters, has the fatty matter a pernicious action? I think these questions have not

yet been answered. I neither pretend to specify all the possible cases, nor to formulate a theory invulnerable to criticism; I limit myself to describing the results of some observations and experiments, and to stating the conclusions which I believe I have logically drawn from them, submitting the whole to the appreciation of specialists.

Properties of greasy-lime deposits.—From a much damaged boiler I gathered a deposit of the following composition:

Carbonate of lime, . . .	83·747
Carbonate of magnesia, . .	2·707
Sulphate of lime, . . .	2·042
Lime in excess, . . .	3·137
Organic matter, . . .	2·240
Fatty matter, . . .	1·010
Oxide of iron, . . .	2·225
Silica, ...	1·900
Water, ...	0·800
Not ascertained and loss, . .	0·192
Total, . . .	100·000

This pulverulent deposit is of a greyish color, adheres but slightly to the heating surfaces of the boiler, and has the peculiarity of not being made wet by cold water, on the surface of which it floats, but during ebullition it is promptly made so and mixed with the liquid.

On the same fire I placed two identical vessels, each containing the same quantity of water, to which, in one, I added a quantity of the above greasy-lime substance. The ebullition in the two vessels was very different, being tranquil with the pure water and tumultuous with the water containing the greasy-lime substance. The latter liquid had a singular appearance: it had become an *emulsion* with a considerably increased volume, being comparable in all respects to milk in violent ebullition. The experiment, which was several times repeated, showed the emulsion to be more intense, other things equal, as the quantity of the greasy-lime substance was greater; but I found the proportion of about one-half of one per centum was sufficient to initiate the phenomenon.

The ebullition of water, whether with ordinary calcareous deposits, or containing different salts, such as the carbonate and sulphate of lime, the carbonate of magnesia—even in the calcined state—sulphate of baryta, etc., either separately or together, produced no similar emul-

sion. Finally, the same greasy-lime substance, on being calcined at a high temperature, lost all its typical qualities: it could be made wet with cold water, and no longer produced any emulsion on ebullition.

The emulsion-making property of this greasy-lime substance must, therefore, be necessarily attributed to the fatty matter it contained; for that the different organic matters which disappeared with the grease by the calcination could have any influence on that property is not supposable, because the nature of these matters is evidently the same as that of the organic substances in ordinary boiler-scale, which produces no emulsion.

I likewise made different analogous experiments with the greasy-lime substance, in which the proportion of grease varied from sixteen to twenty-five per centum, the kind of mineral matter with which it was combined remaining always the same, whether of carbonate and sulphate of lime, or of carbonate of magnesia, or of silica, etc., and I observed the same phenomenon of emulsion except in the following three cases:—

1. That of a deposit containing seventy-six per centum of fatty matter, taken from the hot well of the engine of a sugar manufactory.

2. That of a deposit containing forty-four per centum of fatty matter, taken from a boiler supplying steam to a condensing engine.

3. That of a deposit taken from a part of a boiler which had been exposed to the action of the atmosphere for more than a year. (The greasy-lime substance, on the contrary, taken from a sheltered part of the same boiler, and therefore not exposed to the action of the atmosphere, was emulsion-making.)

These three deposits could be made wet by cold water.

Finally, I made other experiments of the same kind on some greasy-lime substances that were very rich in fatty matter (from thirty to seventy-five per centum). The analyses of these substances disclosed a considerable proportion of oxide of iron, indicating an intense corrosion of the boiler-plates on which they had been deposited. When the substances rich in fatty matter were pulverized they floated on water, but by ebullition the powder soon agglutinated, sunk, and stuck to the bottom and sides of the containing vessel.

But when the substances poor in fatty matter were pulverized the powder did not, on the contrary, agglutinate, but if left, after having produced an emulsion, to sink to the bottom of the containing vessel,

it *did not adhere*, although allowed to remain quiescent for several days. When the liquid was again heated the emulsion was reproduced.

A last experiment, which appeared interesting to me, consisted in making in the laboratory an artificial greasy-lime substance by the vaporization of limy water to which fatty matter had been added. I took the limy water of several factories where emulsion-producing substances had been found, and after ascertaining the quantity of solid matter in solution, I added the necessary quantity of fatty matter in the proportion, approximately, of one-half of one per centum. I discovered that the substances thus formed *in free air* did not possess the emulsion-making property.

This experiment tends to prove, in my opinion, that pressure is necessary to the production of an emulsion-making combination of lime and fatty matter; and it explains the previously mentioned non-emulsion making property of the greasy-lime deposit taken from the hot-well, in which the pressure is but little greater than that of the atmosphere. It also explains the non-emulsion making property of the second deposit containing forty-four per centum of fatty matter. I could not possibly know the pressure under which this last deposit was formed, but as the engine was a condensing one the supposition of a low pressure in the boiler is probable.

It does not appear to me that the composition of the water has the influence on the properties of the greasy-lime deposit which some engineers believe. The different deposits I have examined contained the ordinary elements of spring or river water, but in variable proportions, it is true. If there were any variation in the properties of these deposits it was solely due to the more or less quantity of fatty matter they contained, and to the circumstances which accompanied their formation. I sum up these properties in the following table:

Deposit with fatty matter in strong proportion.	Corrosive property.	Adherence to the metal.
Deposit with fatty matter in feeble proportion.	Formed under low pressure.	Deposit made wet by cold water. Same properties as ordinary boiler-scale.
	Formed under high pressure.	Deposit not made wet by cold water, is made so by hot water, and produces an emulsion by ebullition, which is not adherent to the metal.

Action on the boiler of greasy-lime having a small proportion of grease.—The first boiler accidents attributed to the greasy-lime substance occurred in Germany in 1864; and later, in 1867, Mr. Farcot made an interesting communication to the Society of Civil Engineers on the injuries to a tubular boiler having 1722 square feet of heating surface, erected in the factory of Pont-Remy. These injuries were manifested by large leaks along the upper seams of the interior furnace, and after prolonged investigation, they were attributed to the greasy-lime deposit. By the side of this boiler several combined cylinder boilers were fed with the *same water*, without injury, and this fact is worthy of remark.

From that time such accidents have become frequent; occurring, notably, in a great number of sugar manufactories, and especially to tubular and semi-tubular boilers. In tubular boilers the seams of the inner furnace were ruptured and the stays broken, while in semi-tubular boilers, the plates which received the hottest impact of the flame were ruptured, the fracture following the first circular seam.

These accidents were attributed to the greasy-lime deposit alone, because it was remarked that from the moment the formation of the deposit was prevented, the accidents ceased. The explanation adopted up to the present time is that the greasy-lime substance did not become wet, and being deposited upon the boiler-plates, isolated them from the water, in consequence of which they became overheated and the accidents resulted.

The overheating of the boiler-plates is not to be doubted, for the nature of the injuries prove it, as well as the presence of carbonized matter in the deposit; but, in my opinion, the explanation is erroneous, for the deposit does *not adhere to the boiler-plates*, and further, it *is made wet by hot water*. How can such a theory explain the absence of injury, which I have established to be the fact in other cases, to combined cylinder and semi-tubular boilers fed in the same manner as similar ones which were injured? The emulsion-making property of the greasy-lime substance, of which no account has previously been taken, must here be brought forward, and the explanation of the phenomena can easily be deduced from it.

I remark, at the beginning, that for a boiler to operate properly, it is necessary, in the first place, that the quantity of heat furnished by the furnace, in a given time, shall not exceed the quantity of heat which the metal of the plates can transmit in the same time to the

liquid to be vaporized; and in the second place, that all the heat which traverses this metal shall be integrally absorbed by the liquid.

If this equilibrium is destroyed, either by excess of heat furnished by the furnace or by reason of a diminution in the heat-absorbing power of the liquid to be vaporized, there necessarily results an accumulation of heat in the metal of the boiler plates, producing a considerable elevation of their temperature. This overheating will occur especially in those plates which are acted on by the radiant heat (direct heating surface), in the plates of the connecting pipes of combined cylinder and semi-tubular boilers, and in the tube-plates and crown-sheets of furnaces in tubular boilers, the effect being the production of abnormal dilatations. On the withdrawal of the fire, and even on the diminution of its intensity, the overheated plates cool first, so that during the ordinary use of the boiler its plates are subjected to a succession of dilatations and contractions which at length change the molecular constitution of the metal, strain the seams and end by causing leaks at the rivets and fractures at the weakest places.

Now, in my opinion, the equilibrium which characterizes the normal action of a boiler is broken when the emulsion-making greasy-lime substance begins to form; for the mixture of steam and water which constitutes the emulsion produced by that substance, possesses a less heat-absorbing power than water. The overheating of the plates should now commence, and from that moment accidents are possible.

The extent of the injuries are probably governed by the quantity of the substance present, on the one hand, and by the time during which it acts on the other. In fact, the strength of the emulsion, and consequently the heat-absorbing capacity of the mixture of the substance and water, depend on the quantity of the substance. The influence of the duration of its action appears evident to me, for, in the case of a boiler in ordinary use, the heating and cooling are periodic, so that the expansions and contractions are numerous just in proportion to the time; consequently, as the substance acts longer during a longer time, the molecular changes produced in the metal must be correspondingly greater.

I need scarcely add that for a determined value of the preceding elements, the quantity of heat furnished by the furnace in a given time remains below a certain maximum, the equilibrium of the normal action of the boiler will not be overthrown, in which case overheating could not occur, but the production of steam would be less.

It is conceivable that for each boiler in which the emulsion-making greasy-lime substance is produced, there exists between the quantity of heat furnished or quantity of combustible consumed, the quantity of the substance and the length of time during which it acts, a proportion necessary and characteristic of that boiler as regards its sensibility to the action of the substance. It is also conceivable that when, in practice, one of these three elements passes the limits determined by that proportion, a serious accident will happen, whilst below that limit no accident is to be feared.

Is not this the correct theory for the explanation of the following facts? The semi-tubular boilers containing 1722 square feet of heating surface, which belong to a sugar manufactory in the Department of the Aisne, were all fed with a limy water mixed with greasy water of condensation. They received no injury during the first year, but during the second year they all fractured in an identical manner at the first circular seam.* In a factory in the suburbs of Paris, some combined cylinder boilers, containing 775 square feet of heating surface, have been in daily use for several years, with emulsion-making greasy-lime deposits, but without injury.

The particular sensibility of any boiler to the action of these deposits is not known, as observations in that respect have not been sufficiently numerous, and direct experiments are difficult to make; nevertheless, I believe we may predict that one type of boiler will be more sensitive than another, from the following considerations.

Among the boilers commonly employed in factories, there may be discriminated those of small heating surface, such as the combined cylinder boilers in which that surface rarely exceeds 700 or 750 square feet; and those of large heating surface, such as the tubular and semi-tubular boilers, in which that surface is often 21,500 square feet. I shall adopt this general classification, without deeming it indispensible to fix the exact limits of each category.

Now, in any boiler, the quantity of combustible burned in a given time should be proportional to the heating surface; but, for an economic vaporization, the grate surface should also be proportional to the quantity of combustible burned, and consequently to the heating surface. Various practical considerations however, and among others, the dif-

* After these accidents, the use of limy water was abandoned, and the boilers have been fed with distilled water, since which time no further accidents have happened.

ficulty of maintaining and cleaning the fire on large grates, has led boiler makers to limit the dimensions of the furnaces, from which may be concluded that in boilers with large heating surfaces there is necessarily burned considerable quantities of combustible per unit of surface of grate.

The heat furnished to the *direct* heating surface can be integrally absorbed by the liquid to be vaporized only to the extent of the heat-absorbing power of the latter. Now, the emulsion-making greasy-lime substance has exactly the effect of reducing this heat-absorbing power, rendering it conceivable, in view of the great quantity of combustible burned, that a small quantity of the greasy-lime substance may be sufficient to destroy the equality between the quantity of heat furnished and the quantity of heat absorbed, and to cause, consequently, overheating of the boiler-plates together with the accidents which accompany it. Therefore, the boilers with large heating surfaces are more sensitive to the action of the greasy-lime substance than those with small heating surfaces.

Other facts confirm this: Before the introduction of tubular and semi-tubular boilers into factories, accidents from the greasy-lime substance were very rare, and even its existence was hardly suspected. For example, in the factory at Pont-Remy, the combined cylinder boilers having a small heating surface, acted very well, although fed with a mixture of limy water and greasy water of condensation; but, on the contrary, a tubular boiler of 1722 square feet of heating surface, fed in the same manner, was seriously injured. At the present time, there is in a factory a combined cylinder boiler, containing 775 square feet of heating surface, which works well, although the greasy-lime substance is constantly produced in it. Another factory, on the contrary, has tubular boilers, containing 1722 square feet of heating surface, which have all suffered accidents from the greasy-lime substance.

To sum up: When fatty matter is introduced into a boiler, it forms greasy-iron or greasy-lime deposits, which act on the metal of the boiler in a different manner, according to the more or less fatty matter in them; and according as the pressure under which they are formed is more or less elevated. If the deposit is very rich in fatty matter, it is corrosive, adherent, and causative of overheating at the places of adherence. If the deposit is poor in fatty matter and was formed under a low pressure, it acts simply like ordinary boiler-scale; but, if

it be formed under a high pressure, its action is entirely special, and it can cause accidents by overheating. In the case of any given boiler, the probabilities of these accidents depend on the quantity of the deposit, on the time of its action, and on the quantity of combustible burned. If these three elements exceed certain limits, a serious accident will happen; but, below these limits, the boiler can function *without danger*. Finally, a boiler with large heating surface is more sensitive to the action of this deposit than one with small heating surface.

ON THE INITIAL EFFECT OF THE EARTH'S ROTATION ON THE FREE PENDULUM.

By Thomas William Tobin,
Professor of Physics and Chemistry, Central University, Richmond, Kentucky.

The pendulum defined.

Let the plane of vibration of a pendulum be represented by BAC, Fig. 1. For the purpose of demonstration, let A be considered as the point of origin to which any alteration in the plane BAC is to be referred. AB is the axis of vibration. B, a fixed point about which the vibration Cc occurs.

Fig. 1.

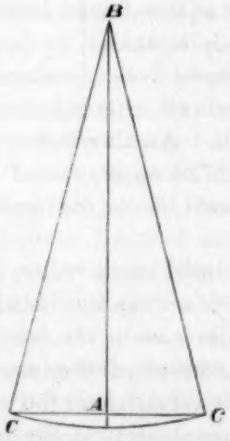
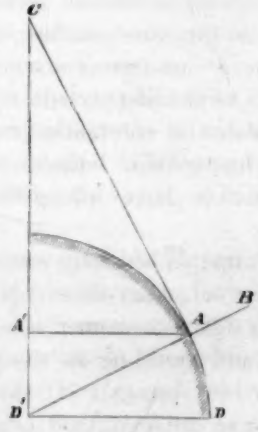


Fig. 2.



Any deviation of the plane BAC may be resolved into the elements AB and AC.

The angle of the earth's deviation.

We will first consider the effect of the earth's revolution upon the element AC, the plane of vibration being north and south, the point A as represented in Fig. 2 and point C perpendicular to AB in the axis of the earth's rotation. The length of AC will remain constant. In Fig. 3 draw CA and the arc AF equal to the space passed through by the point A in a given time, say 24 hours, AF will then be equal to the circle of latitude at A. The line AC will be at CF. Draw FG parallel to AC. It is evident the angle at F will represent the angle of deviation that the earth has undergone in relation to the element AC.

To find the value of the angle F or C its equal:

(Fig. 2) As $CA : A'A :: AD' : A'D'$

or CA : cos. lat. : : rad. : sin. lat.

$$\therefore CA = \frac{\text{cos. lat.}}{\text{sin. lat.}}$$

(Fig. 3.) On CA lay off CL equal to the cosine of latitude (AA') and draw the circle LL'.

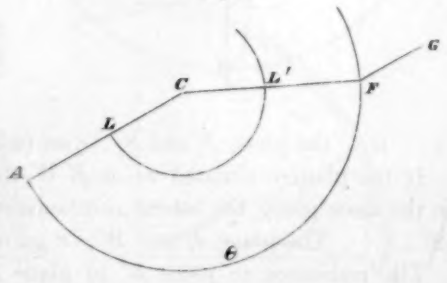
Now circle AF : circle LL' : : CA : CL

and circle AF : arc AF : : 1 : θ

$\therefore CA : CL :: 1 : \theta$

$$\text{and } \theta = \frac{CL}{CA} = \frac{\text{cos. lat.}}{\text{cos. lat.}} = \text{sin. lat.}$$

Fig. 3.



Any inclination east or west being considered as + or — of the line CA, will be + or — at GF and of equal magnitude. Both members therefore being satisfied the equation will remain unaltered.

In revolution around the earth the element AC is perfectly free to continue this relation to itself at all times. In the physical nature of the pendulum there is no opposition offered to the several points A and C. Traversing equal spaces in equal times, they must retain the same relation to each other. Assuming this argument to be true, the formula is not an approximation but absolute.

But the element AB in revolution suffers a constant alteration by gravity and therefore resistance.

THE LATERAL FORCE.

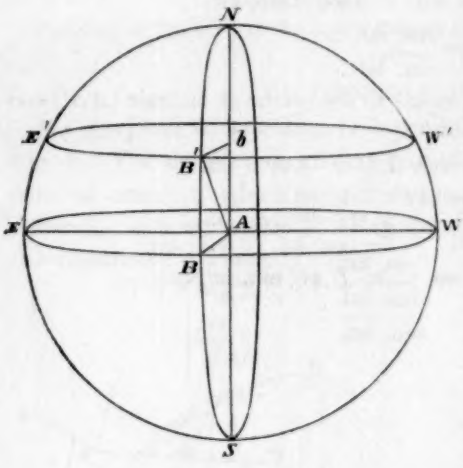
As the element AC in the revolution of the earth remains unaltered, the deviation of the element AB will indicate the whole resistance encountered by the plane BAC.

Its magnitude will be represented by

(a) . . . . The quantity of motion or momentum in the plane BAC. Let this be taken as a constant.

(b) . . . . The amount of lateral deviation of the point B in relation to AC.

Fig. 4.



In Fig. 4 the point A is fixed in relation to the earth, point B in one revolution of the earth would describe the circle EW. If the element AC is situated N. and S., the lateral resistance of point B may be estimated by the circle EW or by its radius AB. As this is the greatest circle that can be described by B and the lateral resistance directly opposed to the direction of B the maximum, we may designate the resistance, r, encountered in one revolution as

(1) . . . . the plane N and S. $r =$ rad. $\times$ 1.

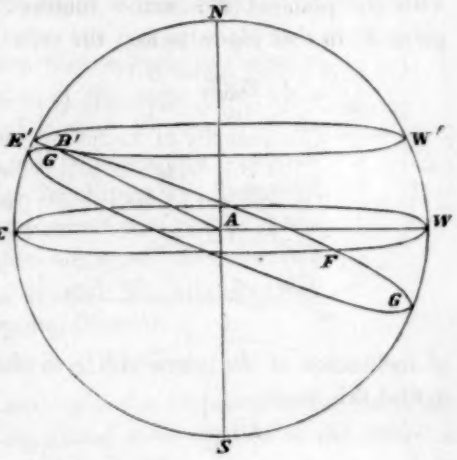
If the plane is situated as at E W, the point B being at all times in the same plane, the lateral resistance will be 0 and we have

(2) . . . . The plane E and W. $r =$ rad. $\times$ 0.

The resistance to point B' in plane N S will be measured by the circle $E'W'$, and as the line AB' must always, by the influence of gravity on the axis of the pendulum make with the earth's axis an angle equal to NAB', the circle $E'W'$ may be represented by cos. lat., $B'b$; for the position on the earth's surface where the pendulum is placed.

Next in regard to point B' let the plane be $E\ W$ as in Fig. 5, the lateral resistance of B' through the circle $E'W'$ will be the normal component of which the space described by B' in revolution is the resultant. The other component is in plane GG and therefore inert.

Fig. 5.



In Fig. 6 $B'A$ is the plane of inclination, $B'W$ the line of direction. $B'W$ is therefore resultant of which $B'm$ and $B'n$ are components.

As $B'm : B'W :: \text{sin. lat.} : \text{rad.}$

$\therefore B'm = B'W \times \text{sin. lat.}$

and the lateral resistance of point B' may be expressed

(3) . . . . the plane N and S. $r = \text{cos. lat.} \times 1.$

(4) . . . . the plane E and W. $r = \text{cos. lat.} \times \text{sin. lat.}$

We have now to consider the plane BAC in any position.

Fig. 6.

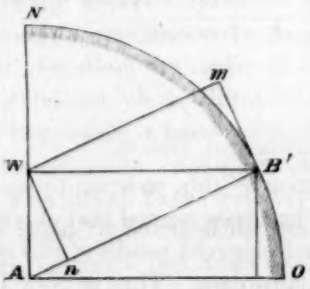
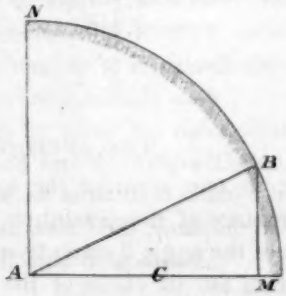


Fig. 7.

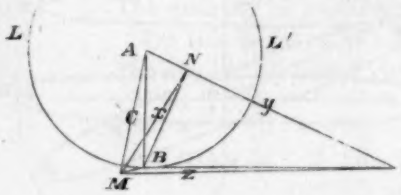


THE PLANE OF INCLINATION.

The normal component $B'm$, or amount of resistance encountered by the point B', is determined by the angle $AB'W$ or its equal $B'AO$. It is evident from the foregoing reasoning that any point in the plane GG', Fig. 5, as for example F, will have resistance, r, measured by

the circle described by it or the radius of that circle, multiplied by the normal component of the lateral resistance to that plane. It is then necessary to ascertain the angle made by any plane passing through A with the plane of the earth's rotation, EW, and the position of the point B' in that plane, to find the value of r.

Fig. 8.



In Figs. 7 and 8 let c be the cosine of latitude, BM the sine of latitude, BOM the given angle of the plane of vibration at B from E and W, LL' the circle of latitute at B. Join AO and draw BN perpendicular to AO. Join AB and NB. BNM will be the angle of inclination of the plane ABO to the plane AMO. It is required to find this angle.

$$c : y :: x : z$$

$$x = \frac{c\,z}{y} = \text{cos. } d \times \text{cos. lat.}$$

in which d = azimuthal angle of the plane of vibration from E and W and x = cosine of angle of inclination of plane of vibration to plane of the earth's rotation.

Substituting this value of d in Equations (1), (2), (3) and (4), the general formula for the initial lateral resistance of point B will be

(5) . . . . $r = \text{cos. lat.} \times \sqrt{1 - (\text{cos. } d \times \text{cos. lat.})^2}$

while the deviation of C is

(6) . . . . $\theta = \text{sin. lat.}$

The effective resisting force.

Let us now consider the application of this resisting force in the performance of the pendulum. It has been argued that an augmentation of the angle θ arises from it and observed results of this angle of deviation are in excess of the calculated data. Thus at New Haven, lat. 41° 18½′ N., the calculated angle was 9·928° per hour (Lyman) observed angle, 9·97. If this theory were true, our formula predicts a deviation when the pendulum vibrates N. and S. at the equator! Is observation in accordance with this fact?

A more rational explanation seems to be furnished in the elliptical motion of the pendulum after starting.

In Fig. 9 let *Ce* represent the original vibration, at the end of given time let the lateral resistance be indicated by BB'. The vibration about B' having regard to the persistence of the plane *Ce* will assume the ellipse whose centre is at B' and foci at C' and c'.

Fig. 9.

If this theory is true we have these ellipses in the same latitude of different magnitudes in the same time when the pendulum vibrates N. and S. and E. and W. At the equator the conjugate axis will be maximum N. and S. and 0 E. and W. At the poles the ellipses will disappear. In general, the magnitude of the minor axis will be determined by the latitude and the angle of the vibrating plane of the pendulum from E. and W., all of which may be inferred from the foregoing formula.

Accidental ellipticity.

The foregoing results are based upon the supposition that the pendulum at starting receives an impulsive force, applied at the centre of oscillation, while the pendulum is at rest in its axis of vibration, *A B*, Fig. 1. Practically, this is never achieved in experiment, and an accidental lateral force is the result. The detention of the pendulum out of the axis of vibration, the method usually employed in starting the experiment, may be determined in the tangentral force of Prof. Stanley. But the most fruitful sources of accidental ellipticity are probably owing to the imperfection of the point of support and the torsion of the suspending medium. In the latter method of starting, unless the point of detention, the centre of oscillation and the axis of vibration are in a common plane, ellipticity is inevitable.

The best results I have obtained were by using the rigid pendulum and clamping the cross-piece described in the "Sine Pendulum," Jour. Franklin Inst., vol. civ, p. 418, so as to confine the vibration to one plane. On releasing the cross-piece, this plane of vibration was free, or nearly free, from accidental disturbing causes.

Coloring to Milk.—It appears that milk is dyed according to the food given to the cow. If fed with *Anchusa tinctoria* they yield a blueish milk, if with *Rheum palmatum* a yellowish, and if with madder or bed straw (*Galium*) a reddish.—*Chem. News.*

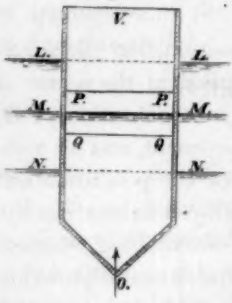
ON THE MEASUREMENT OF TIDAL HEIGHTS.

A METHOD PROPOSED TO ELIMINATE THE ACCIDENTAL ERRORS OCCASIONED BY WAVE-MOTION IN TIDAL OBSERVATIONS, AND TO OBTAIN, UNAFFECTED BY SAID ERRORS AND AT GIVEN INTERVALS OF TIME, THE REAL TIDAL HEIGHTS OF THE SEA LEVEL FROM A GIVEN PLANE TO WHICH SAID OBSERVATIONS ARE REFERRED.

By L. D'AURIA.

Let a vessel V (Fig. 1) be immersed and fixed in the sea, and the water entering it through a small orifice O, placed at its bottom. The sea surface being affected by wave-motion, it will oscillate on the outside of said vessel vertically; and if the horizontal lines LL and NN represent, respectively, the superior and inferior limits of the oscillation there, the velocity of the sea surface on the vessel will be equal to zero, and it will be equal to its maximum when said surface reaches its middle position MM. Inside of the vessel V the surface of the sea oscillates too, and whatever may be its oscillation, its middle position will coincide with MM. Indicating by the horizontal lines PP, QQ, respectively, the superior and inferior limits of the internal oscillation, the velocity of the sea surface inside of the vessel will be equal to zero when in those limits, and will be equal to its maximum when in the middle position MM. But as this velocity depends upon the head of water on the orifice O, when this is equal to zero, or when the external level is in coincidence with the internal one, the velocity of the latter will be equal to zero; therefore, this coincidence will take place in the lines PP, QQ, and it will be easily understood that when the coincidence takes place in PP, the external level must be in its descending phase, and it must be in its ascending phase when the coincidence takes place in QQ.

Fig. 1.



From the foregoing results that the head of water on the orifice O must be equal to its maximum when the internal level reaches its middle position MM. Now supposing the external level in coincidence with the internal one in PP, or in QQ; and representing

by t the period of the waves, in $\frac{1}{4}t$ the internal level will pass from PP or QQ to MM; and in the same time, it is evident, the external level will pass from PP or QQ, respectively, to a position which will be above NN or below LL; therefore, the maximum head of water on the orifice O will be less than the distance between MM and LL or between MM and NN, which we indicate by r; and the maximum velocity of the internal level will be less than

$$\frac{s\mu}{S}\sqrt{2gr};$$

in which S is the area of the cross-section of the vessel V; s, the area of its orifice O; and μ the co-efficient of efflux for said orifice.

Taking for mean velocity

$$\frac{1}{2}\,\frac{s\mu}{S}\sqrt{2gr}$$

and putting

$$\frac{s\mu}{S}=m$$

the amplitude of oscillation of the internal level will be

$$x=\tfrac{1}{4}tm\sqrt{2gr}.$$

But from the Hagen's experiments on sea waves results

$$t=\pi\sqrt{\frac{2r}{g}}$$

therefore

$$x=\tfrac{1}{2}\pi mr.$$

The weather and the situation in which tidal observations are taken are such that it is quite enough to assume $r=0^{m},50$, or $2r=1^{m},00$, as the maximum amplitude of the waves during the observations. Taking $m=\frac{1}{2225}$, will be $x=0^{m},00035$; and with these data we can consider the internal level as being quite unaffected by wave-motion.

Now to investigate the movements of this level by the tide effect, we can suppose indifferently the surface of the sea as being unaffected by wave-motion, because this supposition does not change at all the conditions of the water in the vessel V; but we cannot say the internal level moves the same as the external one, just for the same reasons the effect of wave-motion has been eliminated in said vessel; and we can see *a priori* that during the flow the internal level will be below the external one, and during the ebb the external will be below the internal.

Let l be the distance between these levels at a given instant, and w the velocity of the external level; the variation of l in the following instant will be

$$dl = dt\,(w - m\,w - m\,\sqrt{2gl}\,)$$

from which

$$w\,(1 - m) - m\,\sqrt{2gl} = \frac{dl}{dt} = u\,;$$

and

$$l = \frac{[w\,(1 - m) - u]^2}{2gm}$$

in which u represents the relative velocity of one level in reference to the other.

The velocity of w becomes equal to zero at the high and low water, therefore, at a certain intermediary position of the internal level, it must be equal to its maximum. Now if we indicate by H the difference of heights between high and low water, and by T the time between these positions, the mean value of w will be

$$w_0 = \frac{H}{T}\,;$$

and the maximum value of w will be approximately

$$W = \frac{2H}{T}.$$

As the maximum value of l corresponds to $w = W$ and $u = 0$, it will be

$$L = \frac{W^2\,(1 - m)^2}{2gm^2} = \frac{2H^2\,(1 - m)^2}{gm^2\,T}.$$

The maximum value of u is approximately

$$U = \frac{4L}{T} = \frac{8H^2(1 - m)^2}{gm^2\,T^3}\,;$$

therefore, the value of l, which corresponds to $w = 0$, will be not greater than

$$l_0 = \frac{32H^4}{g^3m^6T^6}.$$

If this value is so small as to be neglected in calculations, we can assume that for $w = 0$, also $l = 0$; and in such case the high and low water of the internal level will coincide in heights and times with the high and low water of the external level. For intermediary positions of the sea level, the value of l will be then

$$l = \frac{w^2(1 - m)^2}{2gm^2} \quad . \quad . \quad . \quad . \quad (1)$$

in which w can be changed for the velocity of the internal level, because the latter being

$$wm + m\sqrt{2gl};$$

it becomes w when, instead of l, we substitute the value (1).

The conclusion will be to take tidal observations from the level of the sea in the vessel V, to avoid the accidental errors occasioned by wave-motion. These observations, which we indicate by

$$h_0,\ h_1,\ h_2,\ h_3,\ \ldots\ldots\ h_n,$$

registered in order of succession and taken at equal and small intervals of time δt, between two consecutive passages of the moon through the meridian, will give us the value of w corresponding to each of them, by

$$w_0 = \frac{h_n - h_0}{\delta t};\ w_1 = \frac{h_0 - h_1}{\delta t};\ w_2 = \frac{h_1 - h_2}{\delta t};\ \ldots\ w_n = \frac{h_{(n-1)} - h_n}{\delta t};$$

and after the corrections

$$l_0 = \frac{w_0^2\,(1-m)^2}{2gm^2};\ l_1 = \frac{w_1^2\,(1-m)^2}{2gm^2};\ \ldots\ldots\ l_m = \frac{w_n^2\,(1-m)^2}{2gm^2};$$

which serve to find the real tidal heights of the sea level from the plane to which the observations have been referred, unaffected by the accidental errors occasioned by wave-motion, and corresponding to each interval of time δt. They are given by

$$(h_0 \pm l_0);\ (h_1 \pm l_1);\ (h_2 \pm l_2);\ \ldots\ldots\ (h_n \pm l_n);$$

in which the sign (+) will be used for decreasing heights, and the sign (—) will be used for increasing heights; or in other words, when the velocity w results positive, the correction l will be taken negative; and when the velocity w results negative, the correction l will be taken positive. [This results from the consideration that the internal level during the flow of the sea is lower, and during the ebb is higher than the external level.]

Now the whole question is to prove that the quantity

$$l_0 = \frac{32H^4}{g^3m^6T^6}$$

is really very small.

Calculating for a tide of $H = 4^m,00$, and substituting $m = \frac{1}{2225}$, observing that $T = 22250$ seconds; will be found

$$l_0 = 0^m,0000088;$$

The practicability of the proposed method seems fully assured by these figures, and we hope it will be taken in consideration by all whom it may concern.

STEEL FOR SHIP-BUILDING.

By JOHN HAUG, Marine Architect and Engineer.

The great progress made in the manufacture of steel, permitting its production in large quantities, of perfect uniformity and homogeneousness of structure at moderate prices, has caused a more general application of this material in cases where lightness, combined with strength, is an important object. Thus it has already been used for moving parts of machinery, steam boilers, bridges, for ship-building, etc.

For steamers of shallow draft, where the utmost lightness is the first question to be considered, its use has been almost compulsory, but its general application for ship-building did, for some time, not make very rapid progress. This has mainly been due to the over-zeal of its advocates, who, using steel of the high tensile strength of forty to forty-two tons per square inch, and reducing dimensions in proportion, soon found that its brittleness and want of ductility made it quite unfit for use, and altogether unreliable, besides requiring the utmost care in heating and working.

After a great number of experimental tests, and a still greater number of practical failures, a mild steel of from twenty-seven to thirty-one tons tensile strength per square inch, with an elongation of twenty per cent. on specimens of eight inches length, was found to be most suitable and entirely reliable, and requiring only ordinary care in its treatment.

The rules of "Lloyd's Register of British and Foreign Shipping" (as well as other classification societies) now recognize the above material as a substitute for iron, and permit a general reduction of twenty per cent. in thickness of plating, frames, etc., from those prescribed for iron ships.

To show the profit which the ship-owner may derive frem the application of this material to a ship, the following example of a trans-Atlantic freight steamer, carrying 3500 tons (dead weight) is given.

If of iron, the hull will weigh about 2500 tons, and the entire ship will cost about $350,000; of steel, the hull will weigh 2000 tons, the total cost being $380,000.

Excess of cost,	$30,000	
Interest,	6 per cent.	
Depreciation, etc.,	6 per cent.	
Total,	12 per cent. on $30,000 per year,	$3600

Extra earnings.

500 tons cargo out.
500 " back.

1000 " on round trip.

Assuming 10 trips per year, will make 10,000 tons,
at $3.00 average freight per ton, $30,000

Makes extra net profit, $26,400 per year,

or 9·428 per cent. on entire cost of ship.

Thus it will be seen that a steel ship would pay a handsome profit where an iron ship would just pay expenses.

In other classes of ships the advantages of using steel will be found in different directions. In river steamers, tugs, etc., if greater carrying capacity were not required, the dimensions of the hull might be reduced to an extent corresponding to the reduction in weight, thus permitting a reduction in cost, in power and in consumption of fuel; or, with the same power, greater speed would be obtained; or, the same dimensions of hull would secure a lighter draft, etc., whichever would best meet the requirements of a particular case.

A few words might be said about the comparative durability of steel and iron. Earlier experience with steel of a high tensile strength had shown that this material corroded more rapidly than iron, but later experiments with mild steel, such as now used for ships, have given a contrary result.

Mr. Henry Bessemer (inventor of the well-known process) immersed a number of pieces of steel and iron plates in diluted acid, and found that the iron was acted upon in a very irregular manner, being deeply furrowed, while the steel always showed a smooth and uniform surface. Some later experiments made at the Terre-noir steel works, in France, showed that the comparative corrosion of different specimens of steel varied almost as their respective percentage of carbon. Steel containing more than $\frac{1}{3}$ per cent. of carbon corroded more rapidly, while that containing less showed a less amount of corrosion than wrought iron.

There can be no doubt that the use of steel for ships will increase also in the United States. Steel manufacturers in Pittsburg have already filled extensive orders for Western boat builders with success, and at such moderate rates that it can fairly compete with iron.

CELLULOID.

"It seems to me," remarked a gentleman the other day, "that about everything we have now, except what we eat, is made out of celluloid." An investigation of the subject almost tends to persuade one that this statement is scarcely exaggerated. Although celluloid was invented nine or ten years ago (by two brothers named Hyatt), its perfected manufacture has been regularly in progress for only about five years, and is considered to be still in its infancy; yet immense quantities of the substance are produced; it is converted into a wonderful variety of forms, and new modes of applying it are discovered almost daily.

Celluloid is a composition of fine tissue paper and camphor, treated with chemicals by a patented process. A rather common impression that it contains gun-cotton is a mistake, which arises from confounding it with collodion. Celluloid, it is said, is entirely non-explosive, and burns only when in direct contact with flame. When crude it looks like a transparent gum, and its color is a light yellow-brown. It can be made as hard as ivory, but is always elastic, and can be readily moûlded into every conceivable form. With equal ease it can be colored in any tint desired, the dye running through the entire substance, and being, therefore, ineffaceable.

All the celluloid made is produced by a single company, with factories in Newark, N. J. This company makes only the raw material, which it sells to various manufacturing companies for so much per pound and a royalty on their net sales. No one can buy it unless the producing company decides to give him a license, which is granted only for the purpose of making some new article that will not interfere with the trade of the companies already licensed. A number of large corporations are now engaged in the various branches of manufacture for which celluloid can be employed.

The cost of the crude article to the buyers is regulated by the producing company according to the use to be made of it and the competition met with in other materials. For instance, $4 or $5 per pound

are charged for celluloid which is to made into jewelry, while only $2 are charged if it is designed for umbrella handles, though there is no difference in the quality of the substance. In consequence of this system there is a similar wide variation in the cost of the manufactured articles.

As a close imitation of ivory, celluloid has made great inroads in the business of the ivory manufactures. Its makers assert that in durability it is much superior to ivory, as it sustains hard knocks without injury, and is not discolored by age or use. Great quantities of it are used for piano and organ keys, to the manufacture of which one company is devoted. So extensive is its use for this purpose that the ivory manufacturers have reduced their price for keys below that of celluloid, in the hope of checking the competition. "It is only a question of who can hold out longest," said a celluloid manufacturer; "but we can make our own elephants, and the ivory men have got to catch theirs."

Billiard balls are made of celluloid at half the price of ivory, and are said to be equally elastic, while more durable. Large amounts are used for combs of every variety, for the backs of brushes and hand-mirrors, and for all kinds of toilet articles which ivory is employed for. Even a fine-tooth comb made of celluloid is twenty-five per centum cheaper than ivory, while in large pieces, such as the backs of hand-glasses, the difference in price is enormous. Among many other articles in which celluloid takes the place of ivory or india-rubber, are whip, cane and umbrella handles, every kind of harness trimmings, foot-rules, chessmen and the handles of knives and forks. Its use in cutlery is said to be especially desirable, as it is not cracked or discolored by hot water.

India-rubber, as a general rule, holds its ground against celluloid, as the latter cannot be sold so cheaply. The celluloid is said to be much more durable, however, and it is superior for pencil-cases, jewelry, etc., where gold mountings are used, as it does not tarnish the metal, whereas the sulphur in india-rubber tarnishes gold which is less than eighteen carats fine. The freedom of celluloid from sulphur, and the natural flesh-color which can be imparted to it, have caused it to be extensively substituted for india-rubber in the manufacture of dental blanks, or the gums and other attachments of artificial teeth.

Celluloid can be mottled so as to imitate the finest tortoise-shell, and its elasticity renders it much less liable to breakage. In this form it is used, like the imitation ivory, for combs, card-cases, cigar-cases,

match-boxes, pocketbooks, napkin-rings, jewelry and all sorts of fancy articles. The substance is employed for similar purposes as a good imitation of malachite and also of amber. It is made into mouthpieces for pipes, cigar-holders and musical instruments, and is used as the material of flutes, flageolets and drumsticks. For drumheads it is said to be superior to parchment, as it is not affected by moisture in the atmosphere.

As a substitute for porcelain, celluloid is used for the heads of dolls, which can be hammered against a hard floor without danger of fracture. Beautiful jewelry is made of it in imitation of the most elaborately-carved coral, reproducing all the shades of the genuine article. Most of the coral tints are bright or dark red, however, as the makers, strange to say, have found that excellent copies of the costly pink coral are not in popular demand.

One of the large manufacturing companies is employed exclusively in the making of optical goods, using celluloid in place of tortoise-shell, jet, etc., for the frames of spectacles, eye glasses and opera glasses. The material is extensively used for shoe tips, protecting the toe as well as metal tips, and having the appearance of patent leather. By shoemakers it is also used for insoles. Large quantities of thimbles are made of it, and it is said to be the best material known for emery-wheels and knife-sharpeners. As a ground for paintings, celluloid has all the advantages of ivory, and photographs can be taken on it which are alleged to be superior to ivorytypes.

Within the last year and a half another branch of celluloid manufacture has been developed which promises to reach enormous proportions. This is the use of celluloid as a substitute for linen or paper in the making of shirt-cuffs, collars, etc. It has the appearance of well-starched linen, is sufficiently light and flexible, does not wrinkle, is not affected by perspiration and can be worn for months without injury. It becomes soiled much less readily than linen, and when dirty is quickly cleaned by the application of a little soap and water with a sponge or rag. For travelers and for wear in hot weather this celluloid linen is especially convenient. It has lately been much improved by the introduction of real linen between two thicknesses of celluloid. Shirt-fronts have been made of it, as well as cuffs and collars, and it is believed that these will prove equally desirable.

Celluloid has been experimented with as a material for neckties, and although the trials have not yet been very satisfactory, it is thought

that they will eventually be successful. For hat-bands and hat sweat-bands it is a trifle more expensive than the materials commonly used, but it is said to be better, as it does not become rusty or greasy. It has also been used lately for watch-cases.

There is a large export trade in celluloid articles to Cuba and South America, and this is constantly increasing. They are not sent to Europe, as the right to manufacture and sell them there has been sold to a foreign company, which has a factory in France.—*N. Y. Evening Post.*

THE "GARY MOTOR."

In a letter to the Secretary of the Franklin Institute, Professor Henry Morton, of the Stevens Institute of Technology, remarks concerning this application of magnetism for the production of motion as follows:

This so-called "Gary Motor" comes before the public in a double character.

First, as a perpetual motion machine, which is to do work without transformation of energy. In this light I think we may at once dismiss it as a fraud or blunder, to take its place with materialization of spirits, and other matters, which are not subjects for the investigation of scientific students.

Secondly, however, Mr. Gary appears as the supposed discoverer of some new facts in reference to the action of magnets, which, though they certainly can no more enable us to create energy than to create matter, may add to our means of utilizing natural forces and existing sources of energy.

In this view his claim of discovering what he calls a neutral line around magnets is worth investigation.

On looking into this matter, however, I find that he has only re-observed a set of phenomena which are so old as to have been described in the *Principia* of Sir Isaac Newton, Book II, Prop. xxiii, Scholium to Theorem, xviii, where I find as follows:

"The virtue of the magnet is contracted by the introduction of an iron plate, and is almost terminated by it; for bodies further off are not attracted by the magnet so much as by the iron plate."

All Mr. Gary's experiments, which will work, are readily explained by the well-known principles of magnetic induction, by reason of

which a piece of soft iron near a magnet is inductively magnetized by the same and reacts upon it, and thus "contracts the virtue of the magnet" and neutralizes its action on exterior bodies.

There is no evidence whatever of the existence of any neutral lines about a magnet, but the very experiments cited by Mr. Gary as proving it simply demonstrate that in certain relative positions the opposing actions of a permanent magnet and a piece of soft iron magnetized by induction from it neutralize each others effects upon a third magnetic body, such as a piece of iron or a compass needlo.

Fully to work out all the relations between the mutual actions of three such bodies in any case is of course a problem of considerable complexity, but by no means a new one, and among many others a very able discussion will be found in the *Philosophical Transactions* for 1831, by Sir Wm. Snow Harris, page 501 et seq., under the title "On the power of masses of iron to control the attractive force of a magnet." An earlier memoir by the same author appeared in the Edinburgh *Philosophical Transactions* for 1829.

Rain of Sap.—On the 22d of August, at 4 P. M., in a calm afternoon, with a temperature of 24° [65° Fahr.], and a clear sky, M. Ch. Musset was struck by the evolutions of some gnats under the spreading branches of two fir trees. Around some yews, under a linden, and about some other shrubs he observed similar swarms of insects, but less numerous; under other trees there were no gnats. He then perceived, falling in the form of a fine rain, an immense quantity of very limpid drops which became visible in the sun's rays. Similar observations were made during fifteen days, at all hours of the day and even in the night by lamplight. The sap is insipid, slightly purgative, colorless at first, but after standing some days it takes a light amber tint. He gives the following hypothetical explanation of the phenomenon. At the close of summer vegetation is checked, the tissues are hardened and consequently transpiration diminishes; but the sap continues to ascend, and, not being employed in assimilation, the excess is poured out by the stomata of the leaves.—*Comptes Rendus.* C.

Substitution of Artificial for Natural Dyes.—In closing his report upon the chemical products at the Paris Exposition of 1878, Gustav Engel anticipates the early displacement of natural coloring materials by artificial dyes. The discovery of artificial alizarine, indigotine and other similar products; the progress which industrial chemistry has made in the application of anilines, by procuring for some of them a permanence which was wanting for some time after their discovery, a permanence, in some cases, even greater than that of the natural products for which they have been substituted; the brilliancy of their tints; their ease of application and the important economy which is secured by their use, are all indications of the most promising character.—*Bull. de la Soc. Industr.* C.

Crystalline Resistance in Mother-Waters.—Guided by theoretical considerations Boisbaudran has made numerous experiments, which have appeared to show, among other things: 1. That the action of different isomorphic crystals is not the same upon the solution of one of them. 2. That the passage from the condition of very slow solution upon a crystalline surface to that of very slow increase cannot be made suddenly, by a slight change in the concentration of the liquid, but that every face remains intact, without either losing or gaining, in a mother-water of which the strength varies within several narrow but easily observable limits. 3. That the resistance to change is modified independently for each system of faces, so that an alteration in external conditions commonly produces a change in the relation of the resistances of two given systems of faces. 4. That, contrary to the opinion of some, there is no mobile equilibrium between a crystalline face and its mother-water, no continual exchange of molecules, but only a continual erosion or a continual deposit, or, between the limits of resistance, neither erosion nor deposit. Some months since M. P. Klocke published at Freiburg some conclusions contrary to these, but they appear to have been drawn without sufficient care. In order to conduct the necessary experiments properly they should be carried on in a place where the daily temperature varies only a few hundredths of a degree. Each of Boisbaudran's experiments required a long time, generally some months, and sometimes years. He worked in a deep cave, hollowed out of a thick rock, and enclosed by double doors.—*Comptes Rendus.* C.

Absorption of Water by Wood.—E. J. Maumené finds that the absorption power varies in different woods, when dried in a vacuum, between 9·37 per cent. and 174.86 per cent. The maximum, 174·86 per cent., or $\frac{7}{4}$ of its own weight, is found in chestnut timber. The moisture contained in wood, in its ordinary state, varies between 4·61 per cent. and 13·56 per cent. The absorption power varies but little in different samples of the same wood.—*Les Mondes.* C.

The Velocity of Light.—There are now in progress at the Naval Academy, preparations for a scientific investigation of an interesting character. Ensign A. A. Mitchelson, U. S. N., having delivered a lecture upon "Light" before an association of scientists, made in preparation for it a series of investigations that induced him to believe that he could determine more accurately than is now known the velocity with which light travels, the two accepted computations differing about a thousand miles in the distance asserted to be traveled in a second. Under orders from the Navy Department, Mitchelson has erected the apparatus to determine his theory practically.

The plan is essentially that used by Foucault, with the exception that a lens of great focal length, and a plane mirror, are used instead of a concave one. This arrangement permits the use of a considerable distance, and consequently gives a longer interval of time, which insures greater accuracy. The displacement of the image of a slit is the quantity to be measured, and this in Foucault's experiments was a fraction of a millimetre, and in the velocity of light could not be determined with any greater accuracy than could this displacement, which would be a fraction of one per cent. In the experiments made by Mitchelson the displacement has been increased to over one hundred millimetres; hence the error introduced by this measurement would be less than one-thousandth of the whole, or less than twenty miles.

Another, though not an essential feature, is the use of a tuning fork, bearing a mirror on one prong, and kept in motion by a current of electricity, by means of which the speed of the revolving mirror can be ascertained with the same degree of precision. The mirror is put in motion by a blast of air furnished by a small rotary blower, which is driven by a steam engine. By this means a very steady speed is maintained. The entire apparatus is nearly finished, and in a short time observations will be commenced at Annapolis.

Siliciuret of Iron.—The committee of chemical arts of the French *Société d'Encouragement pour L'Industrie Nationale* has undertaken the examination of the uses which can be made of this new compound. Prof. Lawrence Smith sent them an ingot weighing about three kilogrammes [6·6 lbs.], with a color like platina and a specific gravity of 6·5. It is easily broken by the hammer, does not rust in the air, is not corroded by concentrated nitric acid, and scarcely by any reagents except fluorhydric acid and melted alkalies at a red heat.—*Procès Verbaux de la Soc.* C.

The Effects of Salt Mining in Cheshire, England.—A deputation from Cheshire has recently made complaint of the injury done to property in the neighborhood of Northwich and Winsford, in consequence of the continual caving in of the earth from the subterranean extraction of brine for many years by the manufacturers of salt. The deputation declares that roads and bridges have fallen in; that the gas and water pipes are broken and destroyed in many places; that many of the houses are cracked and lean to one side, in consequence of the continual undermining of their foundations, and that as yet there has been no legal redress.

The salt beds of Cheshire are composed of massive deposits of mineral salt, buried in the ground 40 metres below the surface of the earth. Naturally, fresh water runs through the beds of sand and marl which cover the mineral salt, dissolves it and changes it into brine. The salt is obtained by means of impermeable pipes or wells that are sunk to the brine; then, by aid of pumps worked by steam, the brine is raised into reservoirs, where an artificial heat causes the liquid part to evaporate. The result of these operations is the salt of commerce, considerable quantities of which are exported to Asia, America, and all the countries of Europe. As there is pumped every year in Cheshire about one billion one hundred million gallons of brine, the damage which is caused to property holders is not astonishing. The superficial soil sinks little by little, the earth of the town becomes broken up, rain water accumulates, and the houses are threatened with ruin. The salt manufacturers urge, on the contrary, that they are doing good, as they employ large numbers of workmen, and attract to the district different industries. This curious state of things is about to occasion in England a lawsuit of great importance, the result of which it is difficult to foresee.—*La Nature.*

Researches on Hydrogen Peroxide.—E. Schoene.—The author has investigated the behavior of hydric peroxide with the oxygen compounds of thallium. He finds that thallium paper is turned brown by the vapor of hydric peroxide in consequence of the formation of thallic oxide. Hence the browning of thallium test-papers on exposure to atmospheric air is by no means a proof of the presence of ozone.—*Chem. News.*

Edison's Electric Light.—This has been advanced a step, and a very important one, as far as the inventor is concerned, by the granting of the patents for the lamp, and for the thermal regulator of the current. From the specifications, it is now positively known that the light is produced by the electric incandescence of platinum and iridium, the exact melting point of which has not been determined, but it is much higher than platinum alone. There have been many forms of these regulators, all based on one principle, namely, the degree of heat produced controlling the amount of the current passing through the metallic conductor, the light being occasioned by the resistance offered, while the regulator is intended to prevent it being heated so high as to melt it. In the case of carbon this is impossible, and consequently the light is much greater from that substance. In Edison's regulator the heat expands the air or fluid in the chamber containing the platinum, and a diaphragm is moved outwards, which in its turn controls the passage of the current by means of contact points of platinum. The diaphragm may give this motion to a lever or spring through which the contacts may be made. Mercury may also replace the air in the tube, and to prevent loss of heat by radiation, two concentric glass tubes may be employed with the intervening space filled with alum water or other poor conductor of heat, surrounding the light, which is very moderate compared with the electric arc. Great improvements have been made within a short time in dynamo-electric machines, notably by Houston-Thomson and other scientists, developing to a great degree their efficiency, and in some of the best forms as high as sixty per cent. of the energy, it is said, is converted into the electric current, leaving but little room for improvement, while but twenty per cent. is wasted in the heating of the machine, etc., which is nearly reversing the available power obtained from our best steam engines, where seventy per cent. passes up the chimney and is otherwise not used.

Chinese Cotton Spinning.—The Chinese Government has bought machinery in Germany, and has engaged experienced engineers and spinners, in order to establish cotton factories of their own, so as to become independent of importations from Russia and England.—*Fortsch. der Zeit.* C.

Influence of Duration and Intensity upon Luminous Perception.—Ch. Richet and Ant. Breguet have experimented with an apparatus which enabled them to produce flashes lasting only $\frac{1}{2000}$th of a second. They find that a feeble light which can be plainly seen when its influence is continued for some time, becomes invisible when its duration is reduced. To make it visible anew, it is sufficient either to increase its intensity or its duration. It can also be made visible by repeating the feeble and brief illumination at least fifty times per second. Colored lights obey the same laws and are always seen with their proper color, whether they are strong or weak, long or short.—*Comptes Rendus.* C.

The Draining of Lake Fucino.—One of the greatest engineering undertakings of the century, well fitted to rank with many attempted in Holland, not even excepting the projected draining of the Zuider Zee, is the successful accomplishment of this work by which the Appenine lake of our boyhood has become a thing of the past, and some 35,000 acres of the richest land recovered for cultivation. The labor of making the tunnel necessary for the task, and other works, has occupied nearly a quarter of a century, and Prince Torlonia has expended on the work more than ten millions of dollars. All the water has disappeared except a small basin used to drain the surrounding district. The greatest length of the lake was formerly some ten miles, and its breadth about seven; while the towns of Avezzano and Pescina are no longer in danger from the sudden rising of the water in this volcanic district. The idea of draining it is not a new one, and the remains of the aqueduct constructed under the reign of the Emperor Claudius were formerly shown to the traveler. This has been made use of in the present undertaking, and after the lapse of so many centuries the people of this Appenine district, some 2200 feet above the level of the sea, are rejoicing over the completed work. Upon visiting the spot a few years hence, how difficult it will be to realize that these vine-clad hills were covered with water within so brief a period.

Compressibility of Gases at High Pressures.—E. H. Amagat has experimented in a shaft with a depth of 380 metres [415·57 yds.] upon the compression of gases by a mercurial column. He reports three sets of experiments upon nitrogen: the first was extended to 208, the second to 330 and the third to 430 atmospheres. The results of these three series are remarkably uniform and the curve which represents them is perfectly regular. Under the pressure of 430 atmospheres the volume of the gas is nearly a quarter greater than is indicated by Marriotte's law, which corresponds to a difference of nearly a hundred atmospheres.—*Comptes Rendus.* C.

New Spectral Rays in Samarskite.—De Boisbaudran has been examining, by the spectroscope, some samarskite, which is rich in didymium. He observed rays or bands which do not correspond to any body hitherto known, nor to the descriptions of the spectra which hav been recently announced by Messrs. De la Fontaine, Lawrence Smith, Soret and De Marignac. The new rays, both of emission and of absorption, appear to represent a single body. The metal which occasions them is precipitated as a double potassic sulphate along with the didymium; its simple sulphate is a little less soluble than that of didymium; its oxalate is precipitated before that of didymium; finally, ammonia separates at first the oxide of the new body and afterwards the oxide of didymium.—*Comptes Rendus.* C.

Imitation Ivory.—Harris' patented imitation ivory is made by dissolving 100 grammes of glue in 1 litre of water, 50 grammes of of alum in one litre of water, and mixing 50 grammes of good bleached cellulose with 3·5 litres of water. The moulds are carefully oiled with a mixture of equal parts of goose grease and lard; then a mixture is formed, in an earthen vessel, of 75 grammes of the glue solution, 200 grammes of the cellulose water, 200 grammes of water, 250 grammes of finely sifted gypsum and 200 grammes of the alum solution. This mass is placed in moulds by a spoon, shaken so as to remove bubbles, and left to set and thicken. It is then removed from the moulds, covered with a woolen cloth, the superfluous water pressed out, and, after it has completely stiffened, the fat is removed by hot water. It is then dried and soaked in a hot mixture of equal parts of wax and stearine. After cooling it is brushed until the ivory lustre shows itself.—*Dingler's Journal.* C.

Increase of Meat Exports.—In 1876 the whole quantity of American meat exported to Great Britain was 16,165,632 lbs. In 1878 the export had increased to 53,661,216 lbs.—*Fortsch. der Zeit.* C.

Locusts in Algiers.—Captain Brocard states that the recent invasion of locusts in Algeria demonstrates some new advantages in meteorological and climatological studies. It has long been noticed that the sirocco and drought favor, in a high degree, the development of these pests, whilst cold and stormy weather prove fatal to them. He proposes to devote himself to a careful study of the observations which he has collected with great difficulty, in the hope that they will lead to the discovery of some simple law for determining upon the measures which will be most efficacious for the destruction or the utilization of the locusts.—*Les Mondes.* C.

An Electric Blowpipe.—M. Jamin.—The author remarks that the electric arc which plays between two carbon conductors is a true current. If submitted to the influence of a neighboring current, of a solenoid, or of a magnet, it experiences an action regulated by the laws of Ampère, identical with that experienced by any metallic conductor put in its place, but as its mass is exceedingly trifling its speed is considerable. The author takes advantage of this fact to submit small quantities of matter to an intense heat. By causing the arc to be driven upon lime, magnesia or zirconia, the light is directed downwards and its intensity is increased at least three-fold.—*Comptes Rendus.*

Detection of Salicylic Acid in Beer.—By M. Blas.—It is found that a quantity of salicylic acid, less than ·075—0·1 gramme per litre, when added to beer, cannot be detected with certainty if the ferric chloride reaction be employed, either with the original beer or after precipitation by lead, or after treatment by animal charcoal. It is much more simple to test for the presence of the acid in the urine voided after drinking the beer, when 0·0012 per cent. can with ease be detected. If 20 c. c. of the urine be examined three hours after the beer has been drunk, it will be found that ferric chloride at first produces a precipitation of phosphates, but after their separation the violet reaction is distinct. For the preservation of light beers 0·5 gramme of salicylic acid is sufficient, but 0·2 gramme per litre must be added to strong beers; more than this quantity is unadvisable, as a taste is imparted to the beer; the addition of salicylic acid to beer cannot destroy any of the integral constituents, acting only as a preservative.—*Jour. Chem. Soc.*

French Sleet.—In a recent storm, the ground and trees in many parts of France were covered with a crust of ice of remarkable thickness for that country. Some of the leaves were loaded with a weight of ice fifty times as great as their own weight. Trees, telegraphic wires and nearly all external objects had a crust of two centimetres ($\frac{4}{5}$ inch). Many branches were broken when the thaw commenced. E. Masse thinks that the drops of water were in a state of superfusion at a temperature below zero, and that the crystallization was started by the simple mechanical contact of the drops with solid bodies.—*Comptes Rendus.* C.

Coffee Parasites.—It seems as though each of the plants which are employed for the food of man must in its turn suffer from the attacks of a destructive animalcule. While the phylloxera is continuing its ravages in the French vineyards, a similar scourge threatens to destroy the coffee plantations of Brazil. In the province of Rio Janeiro the leaves often grow suddenly yellow, and in a short time the tree dies; the trouble seems the more inexplicable because the most vigorous plants, those from seven to ten years old, were the first to succumb. Dr. Jobert found, by close observation, that the roots of the dead plants were covered with excrescences similar to those produced by the phylloxera; the interior of these warts was composed of cells containing worms which measured scarcely a quarter of a millimetre [·01 in.]. Dr. J. estimated that upon a single tree there were not less than thirty millions of these parasites.—*Les Mondes.* C.

New French Observatory.—M. Mascart, the director of the French central meteorological Bureau, presented to a late session of the scientific association the plan for establishing an observatory on the summit of Mont Ventoux, N. E. of Carpentras. It rises suddenly 1960 metres [1·22 miles] above a great plain which extends without any marked interruption to the shores of the Mediterranean; it is easy of access at all seasons and is isolated from any interfering influence by neighboring summits. An observatory at this point would complete for the south of France the system constituted upon the north by the observatory of the Puy-de-Dome, and on the southwest by the observatory of the Pic-du-midi; it would furnish valuable indications for meteorological forecasts, useful both to sailors and to agriculturists, and it will be able to render important service to science in various other ways. The cost of the buildings and road will not exceed 150,000 fr. [$30,000].—*Bull. de la Soc. Scientifique.* C.

Adhesion of Mortar.—In building the Pont de Claix, some experimental blocks were joined by mortar which was allowed to harden for three years, when the mortar was broken by an average load of 10·0125 kilogrammes per square centimetre [142·228 lbs. per square inch]. This experiment seems to show that the adhesion of mortar to stone is only about one-third as great as the cohesion of the mortar itself. The result is noteworthy, as this adhesion is the true measure of the resistance of masonry. Further experiments of a similar kind are desirable, in order to establish formal conclusions.—*Ann. des Ponts et Chauss.* C.

Comparison of Obelisks.—In erecting the obelisk of Luxor more than 200 men and a very complicated mass of machinery were required. Only 25 men and very simple apparatus were used in erecting Cleopatra's Needle upon the Thames embankment. The transport and erection of the obelisk of Luxor cost the French Government nearly 1,500,000 francs; the expenses for the same operations upon Cleopatra's Needle only reached about one-fourth of that amount. The following figures give a comparison between the two obelisks:

	Cleopatra's Needle.	Obelisk of Luxor.
Height,	68·5 ft.	74·9 ft.
Volume,	2528·98 c. ft.	2945·62 c. ft.
Weight,	186 tons.	225·9 tons.

—*Ann. des Ponts et Chauss.* C.

Elasticity of Alloys.—M. Phillips reports some experiments for the determination of the coefficient of elasticity and of the limiting elasticity of different bodies. He refers especially to a new alloy which was melted and cast by Matthey of London. Its density at the freezing point is 21·6139. Its composition is:

Platinum,	80·660
Iridium,	19·079
Rhodium,	·122
Iron,	·098
Ruthenium,	·046
	160·005

This alloy is so malleable and ductile that M. Sainte-Claire Deville possesses a thread of it which is only a few hundreths of a millimetre in diameter and is scarcely visible. A hundreth of a millimetre is only $\frac{1}{2500}$ of an inch.—*Comptes Rendus.* C.

A New Academy.—On the 13th of January the Humboldt Academy was opened in Berlin. The object of the institution is to furnish an opportunity to supply special deficiencies of education to persons who have not been able to avail themselves of a regular course of university instruction.—*Fortsch. der Zeit.* C.

Lime Cartridges.—Unslaked lime may be substituted for powder in quarries if it is compressed into cartridges, placed in the drill holes and then saturated with water. By using these cartridges in coal mines there is less waste from small coal than when ordinary powder is employed, and there is less danger of accidents from the flying fragments and from vitiated air.—*Fortsch. der Zeit.* C.

Soundings in Algeria.—Commandant Roudaire reports that two soundings have been completed and a third is under way. After penetrating to ten metres [32·8 ft.] below low water level he found nothing but sands and marly clays. The Arabs come in flocks in search of work. It would be easy to obtain any number at 90 centimes [18 cts.] per day. Fresh water is found at the depth of four metres [13·12 ft.] below the surface of the isthmus of Gabés, even at points which are most elevated above the level of the sea. The advantage of this supply will be readily seen upon reflecting that in the piercing of the isthmus of Suez it was necessary first to employ 2000 camels to bring water to the workmen, and afterwards to bring the water of the Nile along the docks by means of a canal.—*Comptes Rendus.* C.

Wood Dyeing.—G. A. Schoen wished to give an old appearance to some articles of oak wood by rubbing them with oil of aniline, which, as is well known, browns rapidly, but he could only produce a mahogany tint. He then first painted the wood with a solution of aniline salt which penetrates the wood very rapidly, and colors it yellow. He next gave a coating of a solution of caustic soda, to set the aniline at liberty, when there immediately appeared a deep brown hue like that of old oak. The same effect was observed in walnut, plum and other wood. He was equally successful in giving a black tint to various kinds of wood by impregnating them successively with aniline salt, bichromate of potash and soda, allowing them to dry after each application. The coloring was very uniform, penetrating the knots as well as the softer portions of the wood.—*Bull. de la Soc. Industr.* C.

Tin in Tasmania.—Tasmania appears to be rapidly becoming a second Cornwall. Four years ago the tin and tin ore exported from the colony amounted to only £7000, but in 1877 it reached nearly £270,000. The tin ore contains some gold, which increases its value.—*Fortsch. der Zeit.* C.

The First Steel Bridge in America.—Arrangements have been concluded by General D. D. Smith, Chief Engineer of the Chicago and Alton Railway, for constructing the first all-steel bridge in America. General Smith will be remembered by his connection with the U.S. Government Board for Testing the Strength of Iron and Steel, experiments which were carried on by him several years ago. His researches have at last brought him to the conclusion that steel bridges can be built cheaper than iron, and be equal in durability. The bridge will be erected over the Missouri River on the Chicago and Alton Railway. It will be of five spans of 350 feet each. The elevation over high-water mark will not be less than 80 feet, at which height the light steel rods of the "Howe truss" will look like silver cobwebs, glimmering in the sunshine. For all its frail appearance, the bridge will have a strength reached by but few existing structures in the world. The total amount of steel used in the construction will be about 1500 tons, equivalent to almost double that quantity of iron.—*Am. Journal of Industry.*

The Electric Light in Salt Mines.—An experiment has recently been made in the application of the electric light in the Marston Salt Mines, near Northwich, England,one of the largest in the world.

The space to be lighted is seven or eight acres, and 30 feet in height, and a single electric lamp was found sufficient to illuminate the whole, by the reflection from the surfaces of the walls of salt. The distance from the machine to the lamp in the experiment was 300 yards. The The conducting wire was carried down the shaft, which has a depth of 120 yards, then to the lamp, and the metal guides to the cogs were utiilized in the entire circuit. The lamp had an illuminating power of 6000 candles, and the effect from the newly quarried portion of the crystal rock was magical, the reflected light assuming a variety of colors.

Beside the other advantages of the electric light the cost in comparison with candles, heretofore used, promises well for its adoption.—*Iron.*

Hydro-Electricity and Hydro-Magnetism.—M. C. A. Bjerknes reports to the French Academy the results of experiments for verifying his theories. The experiments were performed in the physical cabinet of the University of Christiana with the aid of M. Svendsen, and resulted in the complete verification of his theories. They embraced, first, the action between two pulsating bodies; second, between a pulsating and an oscillating body; third, between two oscillating spheres. In every instance, even when it was necessary to place the vibrating bodies where it was suspected that the disturbing action of secondary forces would become very strong, the results conformed to those of the analytical researches, whenever the vibrations were regular and had a nearly uniform intensity. The attractions, the repulsions, the normal displacements from the central line, and even the deviations around the centres of the oscillations were such as his formulas had announced.—*Comptes Rendus.* C.

Book Notices.

SLIDE VALVE GEARS. By Hugo Bilgram. Philadelphia: Claxton, Remsen & Haffelfinger. 1878. 12mo, pp. 125.

Steam engine designers fully appreciate the advantages of diagrams for showing the functions of the valve gear graphically, and Zeuner has generally been considered the best, the only difficulty being that, when applied to link motions and other complicated cut-off gears, mathematical and geometrical intricacies have to be unraveled, which is a somewhat tedious process to practical men.

By a modification of Zeuner's diagram, the author of the above work has rendered this process entirely graphical, at the same time securing greater distinctness and clearness with regard to the positions and measurements required.

The introduction gives a clear and concise explanation of the distribution of steam in the cylinder, while Part I treats of the common slide valve, Part II of link motions, and Part III of independent cut-off gears, and the author, even in treating the most complicated problems, fully establishes the simplicity, distinctness and clearness of his diagrams.

Among those matters that are treated in an original yet simple man-

ner may be specially mentioned: area of ports, velocity of valve, scope of the common valve, influence of obliquity of rods, theory of link motions, their irregularities and the correction of the latter, the influence of the mode of suspension, the investigations of different independent cut-off gears, etc. The author's patent cut-off gear, while simple in its construction, is a somewhat difficult problem to study, but may be considered one of the most interesting.

While there are many works on valve gears intensely practical, others again intensely scientific, the present treatise may be called "practical on a true scientific basis," and for this reason it will be especially valuable to students. J. H.

THE RELATIVE PROPORTIONS OF THE STEAM ENGINE. By W. D. Marks. Philadelphia: J. B. Lippincott & Co. 1877. Small 8vo, pp. 161.

Legion is the number of *Hand* and *Pocket* books that treat of the above subject, but the rules given by the majority of them are of the most rude and empirical kind; generally all the proportions are deduced from the diameter of the steam cylinder; sometimes the stroke and pressure of steam may be taken into consideration.

Now this might be well enough for a workshop, where only one style or class of engine is built, but it will inevitably lead to failure at the least departure from the beaten track.

The above work is written with a view of effecting a radical cure of this evil, by going back to first principles, in investigating the actual strain upon each part of the steam engine, and proportioning it in accordance with the laws of the strength of materials. This treatment also gives students a thorough understanding of the principles of constructing details, freeing them from the necessity of mere copying and following precedents.

The author frequently cites and refers to eminent writers like Weisbach, Reuleaux, Rankine, etc., sometimes simplifying and condensing their too intricate arguments.

The articles on piston and connecting rods (both iron and steel), showing how far in practice some theoretical considerations may be neglected; those on crank pins, journals and boxes, also investigating the influence and work of friction; on the action of the reciprocating parts; on different forms of cranks; on flywheels, etc., are interesting, and show considerable original research. J. H.

THE STRENGTH OF MATERIALS. By William Kent, M. E. New York: D. Van Nostrand. 1879. 16mo, pp. 139.

This little book is written with various objects in view, the first and most important being to show the wrong basis on which the tests (as a general thing) are made, having for results figures which are not compatible. This is owing, as the author justly explains, to the want of harmony in the experiments; for example, it would be absurd to compare the strength of two metals of the same nature that had been submitted to a pressure of several thousand pounds when the samples chosen were not of the same length or section, etc. We are sorry to say that such is the case, and our engineers rely too much upon experiments of others rather than their own, having for results accidents too numerous to mention. If these tests were complicated or required considerable time, there might be a pardonable excuse, but as a general thing they are most simple, and can be accomplished in a few hours, or even minutes, as the case may be.

The author gives a synopsis of the various methods of testing the strength of materials, and shows the probable error one has to contend with, and the manner of preventing the same. We are glad to see that the graphical comparative diagrams have been recommended, as these give the experimenter a much better idea of what he is to expect than the tables that too frequently help to fill a volume. In conclusion, the reviewer would state that the interesting articles by Professor Thurston and Mr. Townsend which have appeared in this journal are frequently and judiciously referred to. W.

FORMULÆ FOR THE CALCULATION OF RAILROAD EXCAVATION AND EMBANKMENT. By John Woodbridge Davis, C. E. New York: Gillis Bros. 1877. 8vo, pp. 106.

This method consists in finding first an approximate volume by averaging end areas, and if greater accuracy be desired, it may readily be obtained by applying a formula for corrections which gives the difference between the approximate and true contents for ground of any figure. The results are systematically arranged, and the labor of calculating continuous excavations over very irregular ground is greatly abridged. The work is used as a text-book in a number of our engineering schools, and the method is destined to become general. We can cheerfully recommend it. H.

LES PONTS DE L'AMERIQUE DU NORD ETUDE, CALCUL, DESCRIPTION DE CES PONTS. Par L. Ant. Comolli, Ingénieur. Paris: Lefevre. 1879. 2 vols. Text and plates.

This work is a treatise on the various systems of iron, wooden and combination bridges erected, or in process of construction in America. The text (a quarto) contains 213 diagrams and figures illustrating the various systems, and gives a brief analysis with strain diagrams. The folio atlas contains 54 plates of bridges, *in situ*, with details and dimensions.

The theoretical discussions are based upon the method of moments, and for the strength of materials the formulæ of Hodgkinson and Gordon are employed. The analyses are simple and clear, and the work generally quite complete. We fail, however, to find more than a single instance of the tubular girder, and the greatest type of that class, viz., the Victoria bridge, is not mentioned.

The same may be said of the magnificent structure crossing the Mississippi River at St. Louis, of which only a brief notice is given in the text, extending over a few lines. The plates and paper are not of a very good quality, but sufficient to illustrate the work, and all that should be expected for the very reasonable price at which it is offered—45 francs. H.

RAILWAY SERVICE. Trains and Stations—describing the Manner of Operating Trains and the Duties of Train and Station Officials. By Marshall M. Kirkman. Published by the Railroad Gazette, New York. 8vo, pp. 271.

This is a practical little work on the important subject above indicated. The duties of operating roads are sometimes entrusted to inexperienced or careless men, who risk the lives of their patrons by neglecting ordinary precautions. With such a guide as this manual before them, and the exercise of proper care, any manager should be able readily to eliminate from travel all accidents except those resulting from breakage or fire.

The author has carefully compared the numerous systems in use in both England and America, and gives his results in a clear and condensed form, with numerous rules for making up and dispatching trains, methods of signaling, rights of trains, instructions to employees, and all kindred subjects, constituting a manual which should be in the possession of *every* railroad employee or agent. H.

TURBINE WHEELS. By Prof. W. P. Trowbridge. New York: D. Van Nostrand, 1879. 16mo, pp. 88.

TREATISE RELATIVE TO TESTING OF WATER WHEELS, ETC. By James Emerson. Willimansett, Mass.: Published by the Author. 1878. 16mo, pp. 216.

These two works are grouped in one notice as presenting the two extremes of information desirable to possess in turbine construction.

The first treatise is one of a series of reprints from *Van Nostrand's Magazine*, which have been published separately under the name of "Science Series," intended to convey information in physics and mechanics from the best authorities with the latest acquired knowledge. In this instance the treatise on "Turbine Wheels" is a simple discussion of the condition of impact and reaction of the stream of fluid in contact with, or deriving direction from contact with, the guide, or blade. This inquiry is divested generally of all mechanical construction, except the exhibition of six methods of combining the pipe for carrying the influent water, the wheel to which motion is imparted by the flow of water and the pipe dispersing the effluent stream; and adopting these methods the study is restricted to some consideration as to the flow of water in contact with blades of accepted shape.

The merit of the turbine as a motor consists in the propositions first demonstrated by Fourneyron, that it was possible to attain with defined relation of dimensions of a wheel having blades of certain shape; through or between which a stream of water was permitted to flow freely, that is, without any obstruction in the nature of a closure, a useful effect nearly equivalent to the complete motive power derivable from a given flow of water, considered as weight falling so far each instant of time. The wheels themselves in crude form mechanically, but typical to most if not all of the recent so-called improvements, had existed for years if not centuries in the mountainous parts of France and Germany, and Fourneyron is believed to have first considered and developed their capability. Although he adapted to practice one form, he was not at all an inventor of that form. He elucidated the possibilities of a whole class of water motors at the time when the science of millwork allowed the economic substitution of metallic construction for the old wood work of the millwright. The turbine of to-day, as a whole, not a particular form, is Fourneyron's. Not that some one else would not have initiated the consideration, had Fourneyron not done so, but that he and he alone did initiate it in its totality.

The study commenced by Fourneyron was pursued by others, of whom

notably Weisbach, the most thorough investigator in practical mechanics in this century perhaps, added most to the theory of the turbine. It is not to be denied that the best authorities in theory make mistakes. The computations of daily life are full of blunders. Weisbach is freer from error than most other authorities and he is more complete in his theory. There are certain things which become accepted in text books. Thus the proposition, which is the foundation of the Poncelet wheel, that maximum effect is obtained when the water enters the wheel without shock and leaves it without velocity has had general acceptation as a theory, while the impossibility of the conditions have been admitted, and Weisbach with others have pursued their investigations on more tenable bases. The assertion may remain, the application is completely ignored.

The student in science or in the limited branch of practical mechanics who *accepts* authority most inevitably go wrong; he has two causes of error, first that in his text book, and second that of his reading of his text book. "Prove everything and hold fast to that which is good." It remains to say that this little treatise of Prof. Trowbridge is a valuable addition to the study of the turbine.

The second work by Mr. Emerson is a singular collection of experimental and other data on sundry and several patented turbines. Unless some singular peculiarity call for a new study, the mill-owner of to-day must seek some turbine which has a commercial existence; one of which the details of construction shall give a durability in service as well as a high theoretic economy. From this book as authority the would-be purchaser can take a choice. It is a book calculated to instruct him especially as to who will accurately test his turbine after he has purchased it. It may not be so happy for the purchaser to appreciate that he has to deal with men who, as turbine builders, are asserted by Mr. Emerson to be incapable of doing "*a strictly honorable turbine business under existing circumstances*" (the italics are in the original). People will buy fast horses, and they will get cheated. "Purchasers require the highest results at the lowest prices, and there are scores ready to guarantee such, so far as talk is concerned."

As a collection of data of patented turbines having had commercial standing the past ten years, this book of Mr. Emerson is a desirable possession to the hydraulic engineer, and will yearly become of greater value when the publication shall exhibit what one is free to adopt in the details of construction of the correctly proportioned turbine. B.

VOUSSOIR ARCHES APPLIED TO STONE BRIDGES, TUNNELS, DOMES AND GROINED ARCHES. By William Cain, C. E. New York: D. Van Nostrand, 1879. 16mo, pp. 196.

This little treatise forms No. 42 of Van Nostrand's Science Series, and is a continuation of No. 12 of the same series. The author has endeavored to introduce to American readers the fundamental principles of Dr. Scheffler's theory of arches. We do not understand why at this day an effort should be made to revive a theory which, though unquestionably the best at the time of its publication (1857), has since been greatly improved and almost entirely superceded by the method of graphical statics. But, as the treatment is simple and limited to practical cases, and as the results are nearly the same as those given by later theories, it may be useful especially to those who are unaccustomed to graphical solutions. In the first number the author considered incompressible voussoirs, in the present the effect of the compressibility of the material is examined. The ultimate conclusions, however, are found to be the same as before, but the applications have been greatly extended. After giving some general principles, one of which, asserting the entire absence of tensile strains in a voussoir arch, we think should be seriously doubted; the author investigates the stability of arches in general, adding some practical suggestions. Then he shows the influence of spandrel fillings and gives the proper dimensions for keys and widths of abutments and piers. Following are some theoretical discussions on the height of surcharge necessary to bring the line of pressure to the centre of the arch ring, and on the lines of pressure corresponding to minimum and maximum horizontal thrust. The latter half of the volume is taken up with a very complete treatment of underground arches (culverts and tunnels), groined and cloistered arches and domes. The author generally recommends even narrower limits for the line of pressure in these various structures than the usual "middle third," and also that the depth of arch stones should always be increased towards the abutment. He occasionally finds it convenient to resort to graphical constructions on account of their simplicity and elegance, but does not consider them in the light of special cases of a general method covering the entire subject. The little book is well filled with practical examples illustrating the various propositions. It is to be regretted that the subdivisions were not more clearly stated and arranged, also that neither a table of contents or an index has been inserted. It requires a careful search among 196 pages to find a

desired problem, and for practical use this is certainly a great inconvenience. H.

The Pattern Maker's Assistant. By Joshua Rose, M. E. New York: D. Van Nostrand, 1878. 12mo, pp. 324.

The title of this work is not conformable to its preface, which sets forth that it is intended "to be useful to apprentice pattern makers and also to practical machinists." An examination of the book is not satisfactory to establish that it will fill either requisite. In no one regard is it thorough. The calling of a pattern maker cannot be set forth with the fulness which the apprentice or machinist requires in the small book now offered, while the tables and data which a competent pattern maker requires for reference are much more extensive than are here given. The common handbooks for the mechanic will be found to contain more full general tables, while the particular ones given are far from convenient for a pattern maker's use. With much novel information in the practice of the pattern room and foundry, there is so much not said, that the work is not a safe instructor to the novice and of little use to the skilled mechanic. B.

Franklin Institute.

Hall of the Institute, April 16th, 1879.

The stated meeting was called to order at 8 o'clock P. M., the President, Mr. William P. Tatham, in the chair.

There were present 154 member and 29 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers and reported that at the last meeting 8 persons were elected members of the Institute, and reported also the following donations to the Library:

Bulletin of the Royal Academy of Belgium. Vol. 1, 1832, to Vol. 46, 1878, inclusive.

Indexes to First Series, 1832—1856, and Second Series, 1857—1866.

Annuaire of the Academy, 1846 to 1858, and 1860 to 1879, inclusive. From the Academy.

British Patent Specifications and Drawings. From Nos. 4501 to 4949, 1877, and from No. 1 to 1200, 1878.

Disclaimers and Memorandums of Alterations. No. 1408, 1870; 3101, 1873; 3217, 1876; 244, 2294, 3011, 3213, 1878.

Abridgments of British Patent Specifications relating to
1st. Agriculture. Div. 1. Field Implements. 1867—1876.
2d. Bleaching, Dyeing, etc. Part 3. 1867—1876.
3d. Letterpress and Similar Printing. Part 2. 1858—1866.
4th. Photography. Part 3. 1867—1876.
5th. Washing and Wringing Machines. Part 2. 1867—1876.
London, 1878.

Report on the Meteorology of India in 1876. By H. F. Blanford. Second year. Calcutta, 1878.

Report on the Administration of the Meteorological Department of the Government of India in 1876–77.

Indian Meteorological Memoirs. By H. F. Blanford. Vol. 1. Part 2. Calcutta, 1878.
From the Meteorological Department of the Government of India.

Quarterly Weather Report of the Meteorological Office. Part 4. October—December, 1875. London, 1879.
From the Meteorological Committee of the Royal Society.

Reports and Charter and By-Laws of the Fairmount Park Art Association. 1871 to 1879. From J. B. Cox, Secretary.

Atmospheric Electricity. By David Brooks. Philadelphia.
From the Author.

Sixth Annual Report of the Lowell Water Board to the City Council. January 13, 1879. From A. A. Haggett, President of the Board.

Quarterly Report of the Chief of the Bureau of Statistics. Treasury Department. For three months ended Sept. 30, 1878.
From Chief of Bureau of Statistics.

Jura Trias Section of Southeastern Idaho and Western Wyoming. By A. C. Peale, U. S. Geol. and Geog. Survey. From the Author.

Verein der Deutschen Ingenieure. Verzeichniss der Mitglieder. 1879. Berlin. From the Society.

Transactions of the American Institute of Mining Engineers. Vol. 6. May, 1877, to February, 1878. Easton, 1879.
From the Institute.

Geological Survey of Japan. Report on the Second Year's Progress of the Survey of the Oil Lands of Japan. By Benj. Smith Lyman. Tokei, 1878.
From K. S. Otori, Chief Secretary of Public Works of Japan.

Ninth Annual Report of the Board of Directors of City Trusts. 1878. From the Directors.

Annual Report of the Operations of the United States Life-Saving Service for the Fiscal Year ending June 30, 1878.
From the Treasury Department.

Report of the Philadelphia Yellow Fever Committee. Appointed Aug. 22, 1878. From the Committee.

Annual Report of the Friends' Free Library and Reading Room, with Catalogue of New Books. From the Library.

Annual Report of the Director of Harvard College. Presented Nov. 14, 1878. Cambridge, 1879. From Prof. E. C. Pickering.

Transactions of the Literary and Historical Society of Quebec. Session of 1878. Quebec, 1879. From the Society.

Annual Report of the State Geologist of New Jersey. 1878.
From the State Geologist, G. H. Cook.

Publications of the Royal Institute of Superior Study, Florence, Italy, as follows:

Session of Philosophy and Philology. Vol. 1 and Vol. 2. Parts 1—5, 1875—1877.

Il Commento Medio di Averroe alla retorica di Aristotele. Fascigalo 1. 1877.

Session of Physical and Natural Sciences. D. G. Gavanna. Studi E. Ricerche sui Pichogonide. Part 1. Anatomy and Biology. 1877.

Session of Physical and Natural Sciences. Vol. 1. 1877.

Session of Medicine and Surgery. Vol. 1. 1876.

Opere publicate dai professori della sezione di scienze fisiche e Naturali del R. Instituto superiore.

Annual Report of the Adjutant-General of Pennsylvania for 1878.
From J. W. Latta, Adjutant-General.

Astronomical and Meteorological Observations made during the Year 1875 at the U. S. Naval Observatory. Rear-Admiral C. H. Davis, Superintendent. Washington, 1878.
From Naval Observatory.

Specifications and Drawings of Patents, U. S. Patent Office, for October and November, 1878. From U. S. Patent Office.

Mr. George Richards read a paper on "Machines and Implements for Measuring." An interesting discussion followed the reading of the paper, participated in by Messrs. Shaw and Jenks.

Mr. Goodwin described his Gas Stoves, and pointed out their merits, and their economy over the ordinary cooking range. A variety of sizes of stoves were exhibited.